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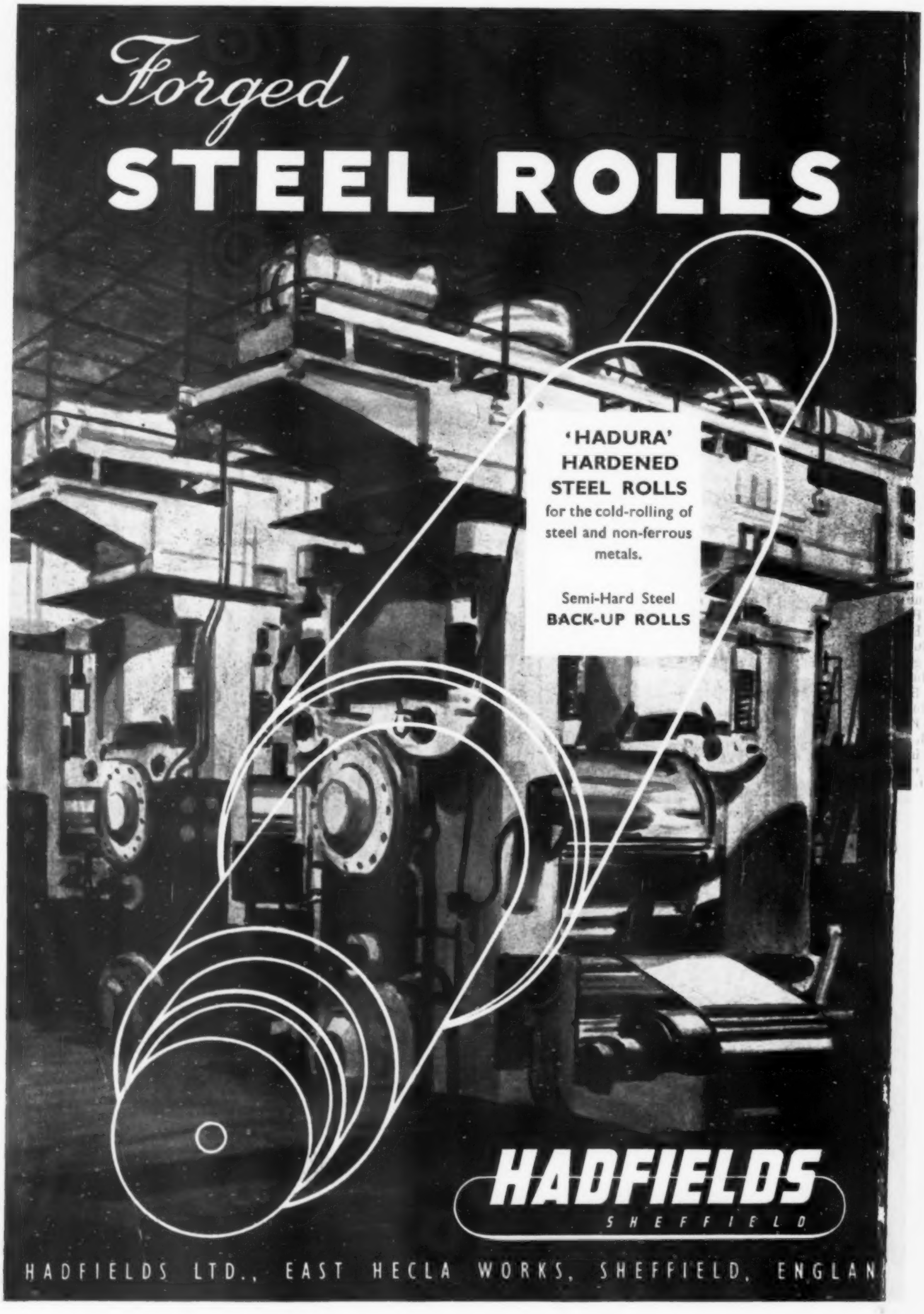
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INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE "METALLURGICAL ENGINEER"

JANUARY, 1955 Vol. LI. No. 303

Steel Review

SINCE 1946, when the steel industry's expansion programme was announced, steel production has gone up by nearly 6 million tons, or 45%, a relative increase comparable with that which has taken place in the United States in the post-war period. Although at the time of writing the figures for 1954 are not available, it looks as though the steel output will be of the order of 18·5 million tons—an increase of almost a million tons over last year's figure of 17·6 million. The year which has just closed has been one of somewhat uneven progress in certain sections of the industry, supply exceeding demand at one period, while the reverse held good at another.

When the year opened, the only difficulties from the standpoint of supplies were plate and sheet. The demand for plate had shown a steep increase in the preceding years, but the difficulties were mainly overcome by the early months of 1954. The same cannot be said, however, of sheet, where the exceptional spurt in sales of motor cars, containers, domestic appliances, etc., considerably intensified the demand for strip mill qualities. Despite an increase of some 15% in production, and slightly lower exports than in 1953, it has been necessary to permit the duty-free entry of about 175,000 tons of imports.

So far as tinplate is concerned, the past year has witnessed a notable recovery from the somewhat depressed conditions ruling in 1953. When home demand did recover, however, it rose to a level higher than ever before, and, because it was not possible to re-open all the closed mills, home consumers could not be entirely satisfied from U.K. sources without a serious reduction in tinplate exports. This undesirable prospect has been avoided by suspending the import duty on tinplate.

Although alloy steel production reached a peak of 1,135,000 tons in 1952, largely as the result—both direct and indirect—of rearmament, the production for 1954, at around 1,070,000 tons, still represents a larger relative increase since 1950 than that recorded for non-alloy steels. Alloy steels being largely used to meet exacting conditions of service, it is essential that they should be of the highest quality, as should the semi-finished material going forward for further hot or cold working. Failure to meet this requirement, even though the properties of the finished product may not be appreciably affected, can lead to untold difficulties in working operations such as wire drawing. Those who have to contend with such difficulties—and, unfortunately, they do exist—tend, not unnaturally, to regard the accounts of expanding capacity and increased output with a somewhat jaundiced eye.

Substantial additions to iron- and steel-making capacity are due for completion in 1955. On the blast furnace side the increment of capacity will be very considerable. First, the industry will have the full benefit of three-furnace operation at Redbourn, Ebbw Vale and Barrow, and of the new stack just completed at Bilston. Other new furnaces due to be blown in during the year include the second 27-ft. unit at Shotton (April); the first of two being built by Lancashire Steel (September); the first of two 27 ft. 6 in. furnaces at Dorman Long's (year-end); a 29-ft. furnace—the largest in Europe—at Margam (August); and one at South Durham in September.

This obviously implies the need for more coke—almost all of which will be provided from the industry's own ovens. An additional battery has just been brought into commission at Ebbw Vale while a second battery of 88 ovens will shortly be completed at Shotton, thus doubling the coking capacity at that plant. By the summer another 90 ovens should be brought into service at Margam and 19 more at Redbourn. Before the end of the year the extensions at Guest Keen's Cardiff works should also be completed.

The additional pig iron will provide the essential basis for a further advance in steel production—from 18½ to (it is hoped) about 19¼–19½ million tons in 1955. The 60-ton arc furnace in the new electric melting shop at Samuel Fox's, completed in November, will make a full year's contribution, while Lancashire Steel's new melting shop will be partly in use by the end of the year. There will also be extensions of steel-making capacity at (*inter alia*) the following plants: Ebbw Vale, Clydesdale, Brown Bayley's and John Summers.

As regards the finishing end of the industry, the new plug mill at Corby has been running-in during the past month or two and will be in full production during 1955. Also worthy of note are the following rolling mill developments—all of which are due for completion within the next twelve months: the new five-stand tinplate mill at Ebbw Vale; Lancashire Steel's new cogging mill; the new tandem rotary forge at Stewarts and Lloyds' Clydesdale works; and the Habershon planetary mill. The installation of a more powerful electric drive in the cold reduction mill at Shotton should be finished by September, to be followed later by the electrification of the slabbing mill.

One of the difficulties the industry faces in long-term planning is that of assessing likely demand for particular products several years ahead. Estimates of the future have, therefore, to be reviewed year by year, although capacity cannot be quickly adjusted to any changes that may be made. The biggest problem is set by the flat-rolled products section of the industry, and although current developments at Margam, Ebbw Vale and Shotton will mean an increase in output of the order of 10–15% in 1955, it seems likely that a further increase in capacity will at some time become necessary. A modern wide strip mill, however, with its ancillary iron- and steel-making capacity, costs in the region of £100 million and has an annual output of perhaps a million tons: the timing of the point of embarkation on such a project—which will take several years to complete—is, therefore, a matter for very careful consideration.

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Continued on page 37

Britain's Largest Arc Furnace

60-ton Unit in Operation at Stocksbridge

Tapping the furnace.

IN a works laid down 112 years ago to draw wire for crinoline hoops, Mr. Gerald Steel, Managing Director of The United Steel Cos. Ltd., recently switched-on a new arc melting furnace which, with a capacity of 60 tons, is easily the largest in the country. Although the works—that of Samuel Fox and Co. Ltd., a member of the United Steel Group—has tradition and history, it has always endeavoured to keep in the van of progress. What is believed to be the first cold rolling mill in the world was installed there just 100 years ago, and in the middle of the last century also the second ever Bessemer licence was issued to it. To-day, special alloy and stainless steels for the automobile, aircraft and electrical industries constitute an important part of the production at Stocksbridge. Furthermore, Fox's, who already make 98% of the razor blade strip produced in the United Kingdom, are now exporting to the United States, the home of the safety razor, sufficient steel to make 600 million blades a year. Some months ago, the Company announced that they had successfully entered a market exclusively held by foreign manufacturers for many years, and had produced all-British watch springs, which are now being turned out at a rate of 42,000 a week, with a growing demand.

All these products call for high quality steel, and since the early 1930's, when the Company began to specialise in alloy steelmaking, the open hearth furnaces have been progressively reinforced by electric melting units—first by small, and then large, high-frequency induction furnaces, followed by two 10-ton arc furnaces. In spite of this, electric steel has accounted for quite a minor share of the 250,000 ingot tons which now represents the annual production of the works. The new 60-ton arc unit, which is expected to produce over 1,000 ingot tons per week, doubles the available electric melting capacity and opens the way to the provision of high quality steels in cast quantities convenient for meeting the growing demands of the engineering industries.

It is expected that the high-frequency and small arc furnaces will be increasingly devoted to the melting of stainless, heat-resisting and other highly alloyed steels, and that beneficial results will arise from this measure of specialisation. The new furnace on the other hand will be occupied with the production of types of steel with a relatively low alloy content, most of which will find its way as semi-finished steel to the re-rolling, drop-stamping and tube-making industries, though some of it will certainly be processed within the works in support of the Company's developing interest in special wire and strip.

A more even balance now exists between the Company's open hearth and electric steelmaking resources, but exactly how consumer demand and fuel costs will influence this balance in future, one way or the other, is a matter for conjecture, and one that requires future plans for plant development to be left in a flexible state.

Particular metallurgical significance attaches to this furnace by reason of its size relative to the types of steel it is designed to melt. The use for this purpose of arc furnaces of similar or even larger size is not uncommon in America, but in this country much smaller units have been the rule. This 60-ton furnace is accordingly an innovation in Great Britain and as such is likely to command close attention as a guide to future developments. A brief description of the furnace and its setting may therefore be of some interest.

Raw Materials Handling

In the interests of efficient and unimpeded manufacturing operations, and with an eye to possible future developments, it was decided to house the furnace in a new melting shop constructed on open ground at the west end of the works, and at the same time to reconstitute and extend the adjoining raw material yards so as to serve both the new and the existing shops.

To provide the 100,000 square feet of level site on which the melting shop now stands it was necessary to cut into a hillside and excavate some 750,000 tons of earth ; this excavated material was carried across the valley on to the opposing hillside and is being used to

Control cabin of one of the overhead cranes. The crane driver sits at the controls.

General view of the melting shop showing the furnace on the left and the teeming and cooling pits in the centre.

build up a series of levelled playing-fields within the boundaries of the Stocksbridge urban district.

Apart from excavation work the preparation of the site has involved the laying of some three miles of railroad track and sidings to link up with the general transport system of the works, the bridging of the Little Don River to provide access to the main Sheffield-Manchester Road, and the planting of trees and shrubs to consolidate the exposed ground and furnish a setting in keeping with the rural character of the surrounding land.

The new raw materials stockyard serves both the old open hearth melting shop and the new 60-ton arc furnace, and centralises the handling of raw materials previously undertaken on three different sites. Altogether the yards will accommodate fifty different varieties of scrap steel and pig iron, in addition to more than twenty kinds of alloys for special steel making. The layout includes marshalling yards for incoming materials, transfer and loading sidings under bays served by overhead electric cranes, and marshalling yards for delivery of materials by pan bogie trains.

The stockyard itself comprises two gantries each 90 ft. span and 1,010 ft. long. Each gantry supports two 5-ton capacity electric overhead cranes with limited swing magnets. At the eastern end of the gantries is the alloy store, 50 ft. wide × 222 ft. long, arranged transversely and over which is a " garage " for servicing the overhead cranes. The alloy store is equipped with facilities for weighing and drying the special alloys prior to despatch to the melting shops. Adjacent to the alloy store is the amenities block where provision is made for messrooms, general conveniences, weigh office, laboratory drill shop, etc.

Melting Shop Building

The steel-framed building has been designed with a monitor type roof, making extensive use of Castella beams, with plate type crane girders and columns of fabricated plates spaced at 48-ft. centres. The girders and columns are so arranged as to provide ready communications at high level with protective walkways passing through the web of the stanchions. They also provide easy access to the roof and to the service equipment which has been concealed at crane girder level.

To obtain natural light conditions as far as possible extensive use of glazing has been adopted, its effectiveness being ensured by extensive dust extraction equipment conveying polluted air away from the furnace and casting pits.

The main building block comprises three bays on an east-west axis, the largest on the south side, in which the casting, stripping and cooling of ingots is carried out, being 366 ft. long by 70 ft. wide. This bay is equipped with a 100-ton and two 15-ton overhead electric cranes for duties in connection with these operations, and for serving the refractory stores, ladle pit, drying furnace and cooling pits, which are also located in this bay.

The centre bay—240 ft. long by 60 ft. wide—houses the 60-ton arc furnace and transformer, together with a control room and basement for electricity and other services. Heavy lifting in this bay is catered for by an 80-ton overhead electric crane, and the general work relating to unloading, storage and filling of charging baskets is handled by a 10-ton crane of similar type.

The third bay on the north side, which is of similar dimensions, is devoted to raw materials. Incoming materials are discharged from railway wagons into two timber-lined bunkers divided by a platform, into which is built a 60-ton capacity transfer car and weighbridge. The handling of materials is carried out by a 10-ton overhead magnet crane which loads a charging basket prior to its being conveyed by the transfer car from the weighbridge into the adjoining furnace charging bay, where it is lifted by the 80-ton crane to release its contents into the furnace.

Although the cranes involved have been manufactured by different firms the crane cabs have been made to a standard specification; master controllers are utilised and the cabs are enclosed, the crane driver being in a

sitting position during operation. For dealing with smaller loads of slag-making materials and alloys a Wellman diesel-engined ground-type charging machine, with ram, is used in support of the crane service.

Electricity, gas and other utility services are brought through a centrally positioned service duct arranged laterally under the main buildings and lead from this point to the required service position. To prevent excessive dust deposits in the control room, and to reduce air movements within the main building, clean air is introduced to the furnace position and the control room through the same underground service duct.

Administration of the plant is carried out in an adjoining building constructed on a steel frame which has been clad on the upper floor with a system of non-load-bearing, fully fire-resistant curtain walling, using stainless steel panels as an infilling. This method of construction is in the nature of an experiment in order to gain experience in the use of stainless steel for non-traditional building methods. The system employed is based on a modular approach with a 40-in. grid, the cost of the stainless steel panels being offset by the lightness of the supporting steelwork and foundations and the speed of erection, as the panels can be clipped in as easily as panes of glass.

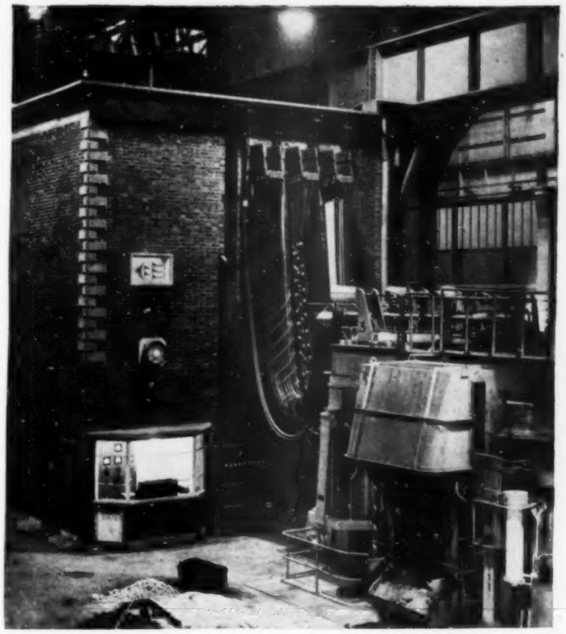
Electricity Supply

Electric power to operate the plant is supplied by the Yorkshire Electricity Board through a ring main system delivering current at 11,000 volts to the melting shop sub-station. It is expected that when the furnace is in full operation the weekly power consumption of the plant will add nearly 1 million units to the 2 million units already being taken by the rest of the works, bringing total consumption up to a level comparable, for instance, with that of nearby Huddersfield.

The furnace equipment is operated from the standard high tension, 3-phase, 50 cycles supply, whilst auxiliaries are run from a 440-volt, 3-phase, 50-cycle, 4-wire A.C. supply. Power to the furnace transformer is controlled by a horizontal draw-out type, triple pole, oil immersed circuit breaker having a rupturing capacity of 250 MVA at 11,000 volts.

The furnace transformer by the English Electric Company is one of 15,000 kVA, 11,000 volts, 3-phase, 50 cycles rating, and is of the circulating oil filled type, the oil being cooled by pumping through an oil-water heat exchange system using some 100 gallons of clean water per minute. It is in two sections, the first transforming up from 11,000 to 22,000 volts, at which voltage the tappings are made, and the second section transforming down to the final output voltage. This voltage can be varied in 21 steps from 325 to 90, and it is a unique feature, so far as large arc furnaces in this country are concerned, that the tapping variations are made "on load."

In the main transformer house accommodation is provided for the main 11,000-volt switchgear and associated control panels in addition to the furnace transformer room and control room. This equipment enables the incoming 11,000-volt supply to be conveyed either directly to the furnace and/or in conjunction with the existing works 11,000-volt works ring main. A low tension switchroom is also provided to distribute and control the outgoing supplies of 440-volt A.C. power and lighting from a 1,500-kVA transformer in the basement, and of 250-volt D.C. power for cranes from a 350-kW mercury arc rectifier similarly situated.

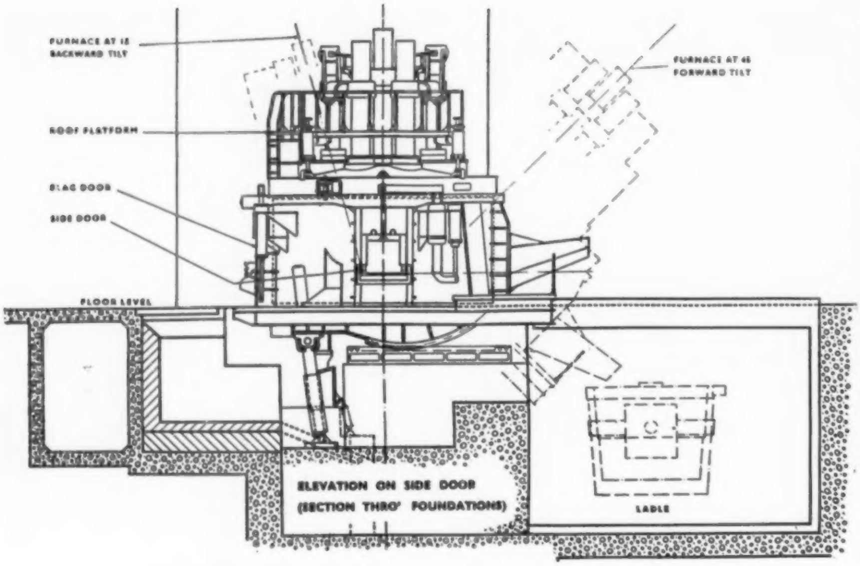


General view of the furnace with the switchgear in the background. The Assyrian ideogram in cuneiform writing above the control cabin has been translated as "A smelting furnace."

The Furnace

The furnace itself was built by Birlec Ltd. under licence from the Pittsburgh Lectromelt Furnace Corporation. Its design follows American practice for large furnaces and embodies the latest features current on both sides of the Atlantic. It is a top charged direct-arc tilting type with three automatically adjusted vertical carbon electrodes each 20 in. diameter, in sections 6 ft. long, connected to the 15,000 kVA power transformer. The electrodes are by British Acheson Electrodes Ltd., and at 20 in. diameter represent a big increase on the 14 and 16 in. diameter electrodes at present in use in this country.

The furnace shell is 19 ft. inside diameter backed with an 18 in. thick refractory lining, the bottom refractory thickness being 27 in. and the roof, which is suspended at four points, 14 in. thick. The whole of the refractory lining has been carried out by two members of the Steetley Organisation—The Oughtibridge Silica Firebrick Co. Ltd., and Steetley Doloma (Processing) Ltd., on the basis of extensive experience on the existing electric furnaces at Stocksbridge. The sub-hearth brickwork is of stabilised dolomite, with Britmag magnesite tubes supported on Britmag magnesite bricks for the walls. Oughtibridge standard silica bricks have been used for the roof. The hearth was built up of rammed tarred doloma for the starting-up period, followed by graphitised doloma for regular production. The taphole is lined with Doloset cement. For hot repair maintenance, gun cement magnesite is applied by means of a B.R.I. gun supplied by Steel Plant Auxiliaries Ltd. Water cooling is applied to the slagging and side doors, together with their arches and jambs, and also to the top of the furnace shell which incorporates a continuous bezel ring of box section to act as a stiffener and also to locate the roof ring.



Section through the furnace and its foundations.

Charging is carried out by lifting the roof and swinging it clear towards the launder on a robust ram, the movement being effected hydraulically. The charging bucket is thereby given complete access. Tilting of the furnace to a maximum of 45° forward and 15° backward is also operated by the hydraulic system. This oil hydraulic system comprises three 30 h.p. motors and pumps situated in the basement, with remotely controlled push button starting and electro-hydraulic operating valves.

Electrode Control

The electrode control by British Thomson-Houston comprises one amplidyne regulator per phase coupled through a power generator to the electrode winch motor. Provision has been made for four amplidyne motor-generator sets, any three of which can be selected. A special feature of this control is that a permanent torque is applied to the winch motor to counter-balance the weight of the electrode masts.

Electrode clamps are made from high conductivity water-cooled copper castings, the slipping and tightening of the electrodes in these clamps being achieved by means of a pneumatically operated opening and spring closing mechanism. Each electrode, together with its supporting arm, weighs 20,000 lb.; they are controlled by electrically-driven winches mounted on the side of the furnace. The wire cable which raises and lowers the electrode is passed over pulleys to give a 4 to 1 advantage and then wound around the winch drum which is coupled to a 725 r.p.m. motor through a 198 : 1 double worm reduction gearbox.

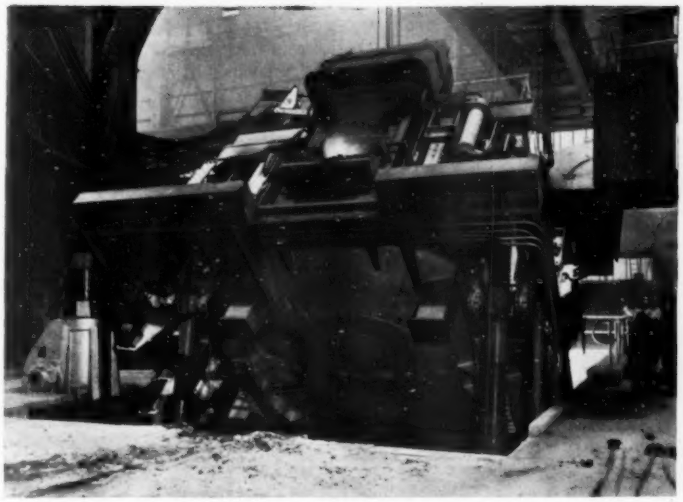
The usual method of controlling the power input to an arc-furnace is to maintain constant arc-impedance by adjusting the position of the electrodes. This principle was adopted in the control equipment, so that the winch motor moves in response to the arc voltage and current causing the electrode to follow the metal as it melts from under the electrode.

In addition to this automatic control, hand control is also provided by appropriate switches. The electrode speed on automatic operation is nominally 6 ft./min., actually it is proportional to the distance the electrode has to travel to attain correct arc-impedance so that the effect of inertia is minimised. During the period before the arc has struck, the downward speed is limited to an arbitrary value to minimise the possibility of electrode breakage. On hand control, speeds for raising and lowering the individual electrodes are initially set at 6 ft./min. and 4 ft./min. respectively. There is an additional master control set to raise the three electrodes simultaneously at 12 ft./min. and lower them at 6 ft./min.

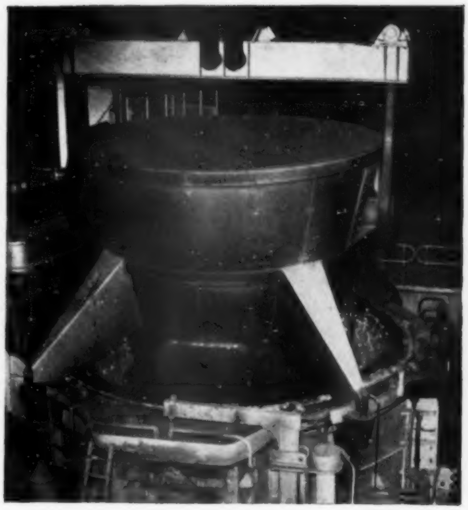
As the electrode is not counterbalanced, the weight is compensated for electrically in such a manner that the winch motors exert a constant lifting force on the electrodes. This constant force is superimposed on the automatic signal at all times, so that there is no tendency for an electrode to run down and dip in the bath. This is most important when low carbon steels are being made.

This equipment was put into service early in November and it was noted that the power input to the furnace was surprisingly constant. In the early stage of the melt when control is most critical power fluctuations were of the order of only ± 10% and after 10 minutes they were even less. Over a number of melts the arc was not extinguished after the initial strike until the "cave-in" period occurred.

Ground charger depositing alloys in the furnace.



The furnace tilted at the completion of its pour, exposing the stainless steel bottom.



The clam-type charging bucket in position over the furnace.

The electrode regulator and other control equipment is actuated from an operator's control desk located in a small room near the furnace. There are individual electrode control switches, a master or group electrode control switch for manual control of the electrodes, and a " Hand-Auto " selector switch so that the operator can select the method of working. Normally, on starting up, the circuit-breaker is closed and the selector switch put in the " Auto " position so that the electrodes come down, strike the arc, and continue to operate at the pre-set current without further attention.

Instrumentation

Instrumentation is adequately provided to facilitate furnace operation and control, indicating and recording equipment being provided for electrical supply including incoming supply current, power supply to furnace, power used per heat, electrode voltages and fault alarm system. Similar facilities are provided for roof and hearth temperature control in addition to equipment for the indication of flow and temperature on the many water supply circuits.

The temperature of the molten metal is measured by means of a Schofield-type platinum/platinum-rhodium thermocouple. A flexible cable connects the couple to a large illuminated dial indicator, 20 in. in diameter, mounted high on the wall and giving the furnace crew a full unrestricted view. A record in ink is made automatically at the same time on a chart recorder in the control cabin.

Safety of plant operation is well covered and in all cases where electrical and mechanical interlocking has been deemed advisable this is provided. For example, electrical interlocks prevent operation of the transformer tap-changing equipment when the circuit breaker is closed, whilst mechanical and electrical interlocks prevent tilting of the furnace unless the roof is closed down on the shell.

Stirring of the Bath

At the time of ordering the furnace consideration was given to the question of stirring the bath by electromagnetic methods, and the plant layout was arranged so that this could be carried out if it were ultimately thought desirable. Subsequent investigation led the Company to the belief that a stirrer could both improve the efficiency of the steelmaking process and lighten the physical work involved, for which reasons the necessary equipment, of Swedish origin, will be fitted to the furnace next year.

Metallurgical Considerations

Out of the present national steel production of some 18 million ingot tons per annum more than 1 million are in qualities which may be broadly classed as special steels. Within this category falls the whole range of stainless, heat-resisting and alloy steels, together with high carbon qualities and others in which a particularly low content of impurities is required Much of this tonnage is satisfactorily made in open hearth furnaces, but considerations of quality make electric melting desirable, and sometimes necessary, when the steel is for engineering components whose life is expected to be long or arduous, or whose failure in service might entail particularly serious consequences.

An increasing demand for quality steels of this nature lies behind the installation of this furnace. Quality control starts with arrangements for sorting and grading incoming scrap, an important point not only in the interests of close analytical control of the final cast composition but also for the detection of unwanted elements such as copper and tin whose presence in quite small amounts can have serious effects on the physical properties of the steel.

As soon as the charge is fully melted a sample is taken for analysis, after which iron ore and limestone are used to make an oxidising slag and thus promote a " boil," during the course of which phosphorus and carbon are reduced to the desired level. Once the required conditions are reached and confirmed by analysis the furnace is tilted and the phosphorus-rich oxidising slag is run off. After the slag is removed the metal is deoxidised by adding ferro-silicon, and a further slag made up of lime, fluorspar and carbon is added.

During this second period reducing conditions are maintained in the furnace and the sulphur content of the steel is thereby brought down to very low limits. Throughout the working period samples are taken and chemically analysed, and when the operator finds that the desired conditions have been reached the final alloying additions are made, the temperature of the bath is checked, and the steel is tapped out of the furnace. The temperature of the molten steel at tap is very important as it has a direct influence on the physical quality of the resulting solid steel.

Whilst it is possible to make steel in an electric furnace using a single oxidising slag, as in open hearth practice, it is the possibility of using the double slag procedure already indicated which is one of the main advantages of the arc furnace. Apart from the very low sulphur and phosphorus contents obtainable thereby, this double slag process, together with accurate control of temperature and conditions inside the furnace, makes possible the production of very clean steel to close analytical limits. Cleanness of steel, that is to say freedom from non-metallic particles such as sulphides and slag, is particularly important as these particles, even though very small, may give rise to localised stresses and subsequent fatigue failure in service, whilst larger particles may produce bursting during forging or drop-stamping into the numerous intricate parts of modern machinery in which alloy steels are now used.

Increased Demand for Special Steels

Mention has been made earlier of the fact that national production of special steels now totals more than a million tons per annum. Until recently production on this scale has been thought of as being dependent on heavy programmes of defence equipment manufacture, but latterly it has become clear that the growing outputs of engineering industries not specifically concerned with defence—and in particular the motor, commercial vehicle and tractor industries—present a different type of challenge to special steel makers. In assessing what will be expected of them in future they have to measure not only the consequences of a possible new national emergency of a military character but the converse and more alluring prospect of the growing strength, stability and expansion of these engineering industries, based on rising standards of peaceful living throughout the world.

With these things in mind there is confidence that the new furnace has a helpful and important role to play in the national economy.

Contractors and Suppliers

List of Contractors

Electric Steel Plant.

Birlec Ltd. ; Henry Boot and Sons Ltd. ; Grant, Lyon and Co. Ltd. ; J. Hadfield and Sons Ltd. ; W. Hamilton Ltd. ; R. Hutchinson Ltd. ; I.D.A. Ltd. ; W. Richardson and Co. Ltd. ; United Steel Structural Co. Ltd. ; Visco Engineering Co. Ltd. ; Wellerman Bros. Ltd. ; Williams and Williams Ltd. ; Yorkshire Electricity Board.

New Stockyard.

Henry Boot and Sons Ltd. ; The Butterley Co. Ltd. ; F. J. Ellard Ltd. ; Grant, Lyon and Co. Ltd. ; I.D.A. Ltd. ; W. G Robson Ltd. ; C. R. Waterhouse Ltd. ; Wellerman Bros. Ltd. ; F. H. Wheeler Ltd.

List of Suppliers of Equipment

Electric Steel Plant and Stockyard.

The Adamson Alliance Co. Ltd. ; Edgar Allen and Co. Ltd. ; Appleby-Frodingham Steel Co. ; Ashworth, Ross and Co. Ltd. ; W. and T. Avery Ltd. ; Birlec Ltd. ; Brightside Foundry and Engineering Co. Ltd. ; British Thomson-Houston Co. Ltd. ; Distington Engineering Co. Ltd. ; English Electric Co. Ltd. ; Head, Wrightson and Co. Ltd. ; S. H. Heywood and Co. Ltd. ; Igranic Electric Co. Ltd.; Lancashire Dynamo and Crypto Ltd.; McCalls Macalloy Ltd. ; Mellowes and Co. Ltd. ; Metropolitan-Vickers Electrical Co. Ltd. ; H. Morris Ltd. ; Newton Chambers and Co. Ltd. ; Samuel Osborne and Co. Ltd. ; C. A. Parsons and Co. Ltd. ; Slag Reduction Co. Ltd. ; Robertson Thain Ltd. ; B. Thornton Ltd. ; The Wellman Smith Owen Engineering Corporation Ltd.

A.P.V. in New Irish Company

The formation of a new company that will be of considerable importance to the Irish creamery and dairy industries, and to Irish industry generally, is announced. To be known as A.P.V. (Ireland) Limited, the new company has been formed by agreement between Booth Brothers Ltd. and Thos. Pearson and Co. Ltd.—both of Dublin and already closely linked by family management—and one of the leading dairy and food engineering companies in Europe, The A.P.V. Co. Ltd., of London. In addition, a company which has long served the needs of Irish creameries, The Creamery Supply Company, for many years controlled by Booth Brothers, will now be taken over completely by the new company and will handle the entire range of A.P.V. products for the dairy and food industries, including heat exchangers, pumps, filters, homogenisers, sanitary fittings, etc.

For some time it has been apparent that there is a growing need in Ireland for facilities for fabricating stainless steel equipment which is gaining such an important place in milk and food industries, and which is being used also in canteens, hospitals and in many other directions. The new company will commence to manufacture all stainless steel equipment in a factory which is being reconstructed at Drimnagh, Dublin.

The chairman of the new company is Mr. R. C. Booth, who is also chairman of Thos. Pearson and Co. Ltd. The other directors are : Mr. B. E. Booth of Booth Brothers Ltd., Mr. E. M. Booth of Thos. Pearson and Co. Ltd., and Mr. W. H. Jones and Mr. R. M. D. Odgers of The A.P.V. Co. Ltd.

Induction Heating Merger

Wickman Ltd., and Wild-Barfield Electric Furnaces, Ltd., announce that agreement has been reached between the two Companies whereby the induction heating business of Wickman, Ltd., has been acquired by Wild-Barfield as from January 1st, 1955. Manufacture of induction heating generators and fixtures will continue as heretofore, and continuity of service is also assured for Wickman A.H.F. induction heating units already in use. Production of the plant will continue at the existing address at Oxgate Lane, Cricklewood, London, N.W.2., for the present, after which it will be transferred to the Wild-Barfield Works, Watford.

All correspondence in connection with induction heating should, for the time being, be addressed to Cricklewood. Mr. F. L. Gladwin, who has been associated with the Wickman in this field since its inception, has been appointed Sales Manager of the Induction Heating Department by Wild-Barfield Electric Furnaces, Ltd.

Copper and Copper Alloys

A Survey of Technical Progress During 1954

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such things as raw material resources, extraction, fabrication, finishing and properties.

THERE has, during the past year, been no lack of activity in scientific and technical development in the field of copper and its alloys, to judge from the abundance of informative literature which has appeared. In a brief review of this nature, it is impossible to do more than to outline a selection of the items which appear to be of special interest and value, and to mention certain others which the reader may like to consult for himself.

The Production of Copper

Commonwealth Production.

The healthy state of copper production within the Commonwealth has been emphasised in several recent publications. In reviewing the Northern Rhodesian Copperbelt as a whole, Prain[1] points out that output has increased by over 50% during the last decade. Two new mines, at Chibuluma and Bancroft, respectively, are being actively developed, and the proportion of electrolytically refined copper is expected greatly to increase. The new refinery at Ndola is to have an initial output of between 55,000 and 60,000 tons of electrolytic copper per annum, with the possibility of eventual expansion to double that capacity.[2] This will undoubtedly have repercussions on the fire refining industry in the home country. The new mine at Kilembe in Uganda is expected to produce about 9,000 tons of copper per annum, and the same smelter, situated at Jinja, will also receive concentrate from the Macalder-Nyanza mine in Kenya.[3]

In Canada it is planned to double the output of Falconbridge by mine development.[4] A new pilot plant is under construction there[5] with the immediate objective of producing copper and nickel, and the ultimate prospect of producing iron also. The Eastern Smelting and Refining Company, proposes to erect a new concentrator with a capacity of 1,000 tons a day[6] and a smelter for copper and nickel at Chicoutimi.[7] Noranda is said to be co-operating in the exploitation of good showings of copper-zinc-silver ore in North Western Ontario. Unofficial estimates are that some 15,000,000 tons of ore have been located there.[8]

In Australia, too, a large deposit of copper has been reported near Alice Springs.[9] The Fifth Empire Mining and Metallurgical Congress, held in 1953, provided a picture of copper production in Australasia. The smelter at Mount Isa operates on a sulphide concentrate containing about 24% copper, which is roasted prior to reverberatory smelting and converting.[10] At Mount Morgan a relatively low grade of concentrate is also roasted,[11] in contrast to the practice at the Tasmanian plant at Mount Lyell where wet concentrate is fed directly into the smelting furnace.[12] A further contribution to the Congress describes the plant of the Electrolytic Refining and Smelting Company of Australia (Pty.), Ltd., of Port Kembla, New South Wales.[13]

Technical Developments.

Now that the ammonia leaching process and hydrogen precipitation of nickel developed by the Sherrit Gordon interests has gone into full scale production, the pilot plant is being used to examine its application to copper.[14] It was established at an earlier stage that copper as well as nickel could be produced by this method, but the economics remain to be assessed. If the pilot trials are successful, the Company proposes to apply the process to the treatment of Lynn Lake copper. It would appear that Mount Morgan Mines, Ltd., of Australia are also interested in the new technique.[15]

Stephens[16] has described pilot plant operations for the roasting of sulphide ores of copper and cobalt to soluble sulphates by the "fluidised-bed" technique. Any iron present is converted to oxide which remains insoluble, while the copper and cobalt sulphates can be leached out. The separation of copper from cobalt by a slagging treatment is under investigation by Johannsen and Emicke,[17] while Evans[18] has prepared a detailed review of the literature on the occurrence of copper in the slags of matte smelting furnaces. A valuable summary of modern practice in respect of refractories used in the smelting of copper has been published by Rochow and McGill,[19] who point out that extensive research is in progress with the object of meeting the more severe conditions likely to arise as smelting speeds are increased.

Two recent patents concerned with the refining of copper deserve mention. One of these[20] covers a method of preparing deoxidised copper directly from tough pitch material containing as much as 0·03% of sulphur, while the other[21] concerns the removal of sulphur from molten copper with an alkali, such as sodium hydroxide, while pouring. It is claimed that over-poled copper can be cast without the risk of unsoundness.

The British Scrap Industry.

Both Baer[22] and Tarring[23] have reviewed the present economic trends in this country in respect of scrap metal utilisation. Both point out that British capacity for refining secondary copper has much increased since the end of the war, especially in respect of electrolytic refining, which now handles some 40,000 tons per annum. Tarring shows that considerably more than a

quarter of the total copper consumption comes from secondary metal, and suggests that Britain is likely in the future to import increasing quantities of scrap to feed the healthily growing industry.

A process has been patented[24] for the recovery of copper and tin from tinned copper, whereby the material is treated with an acid solution of copper sulphate—for example, spent pickle liquor—under such conditions that substantially all the tin replaces copper in solution. The tin is then precipitated as hydroxide by blowing air through the liquid or by spraying it through the air.

Foundry Practice

Special Foundry Techniques.

Accounts have recently appeared concerning certain specialised foundry processes which, though they may have been in operation for several years, can still be regarded as essentially new. For example, comprehensive, well-illustrated descriptions of precision casting in semi-permanent ceramic moulds have been published.[25, 26] The moulds, which are prepared by mixing a solution of ethyl silicate with a high-grade refractory and applying a suitable heat treatment, are said to show economic advantages for runs of up to 500 pieces, while the dimensions of a casting of average size can be held to within $\pm$ 0·005 in. of nominal values.

Though much has been heard lately of the " C " shell moulding process, the modification known as the " D " process is somewhat less well known. According to recent articles,[27, 28] the chief difference lies in the fact that the shells are prepared in a normal core blowing machine from oil-bonded core sand, instead of on a heated metallic pattern from resin-bonded sand. It is said that the cost of the mixture is about one-third of that required for conventional shell moulding. Brown and Worner[29] have described the application of normal shell moulding to copper-base alloys, claiming that it has much to offer for the mass production of small and medium sized components where fine surface finish and accuracies to within 0·003 in./in. are required.

According to a recent press statement,[30] the use of plaster moulds for copper alloy castings is said to result in superior finish and dimensional accuracy. The mould material consists of 70–80% of plaster of Paris mixed with 20–30% of a fibrous strengthener such as magnesium silicate, with small additions of salts and hydrochloric acid to hasten setting.

Considerable interest centres in the application of carbon dioxide to the curing of sand moulds and cores. The idea seems to have originated in Eastern Germany, though at least one relevant British patent has appeared.[31] The British Cast Iron Research Association has compiled a bibliography of 11 references to the subject,[32] while useful descriptions, based on translations of the German work, have been published in this country[33] and America.[34] The underlying chemistry is simple, and is based on the fact that carbon dioxide can readily react with alkaline silicates such as waterglass, desposititing silica in the form of solid silica gel, which acts as a strong but porous bond.

The theory, economics and practical applications of exothermic materials in the foundry have been well reviewed by Atterton and Edmonds.[35] When using exothermic sleeves around the feeder heads, they state that the ratio of feeder volume to the volume of the casting should be about 15–20% for high tensile brass, and 20–25% for aluminium bronze. These figures represent a substantial economy compared with normal practice.

Grain Refinement.

The grain refinement of cast products has already been practised for a considerable period in other metallurgical fields, notably light alloys, but little attention has been paid to the matter until now in connection with bronze and brass founding. The results of an extensive research have been published by Cibula,[36] who shows that grain refinement can be produced in several cast copper alloys by the introduction of fine particles which nucleate crystallisation. Marked grain refinement is produced in bronze and gunmetal castings by additions of at least 0·03% zirconium or 0·2% titanium, especially in the presence of carbon, or upwards of 1·0%i ron. Unfortunately, the paper gives no indication of the advantages, if any, to be obtained by such grain refinement, and it is difficult, therefore, to assess the commercial possibilities of the process.

Pinhole Porosity.

The sporadic occurrence of pinhole porosity, especially near the surface, in brass and gunmetal castings has been traced by Rutherford[37] to the use of wheat flour, either as a mould dressing or in facing sand. The author found that replacement of flour in facing sand by small additions of pelleted pitch gave castings free from pinhole porosity, with surface finish equal to that obtainable by the use of flour.

Pressure Tightness of Castings.

It has long been known that the presence of quite small amounts of aluminium in bronze and gunmetal castings may lead to lack of pressure tightness. Pal[38] has investigated its elimination from gunmetals by blowing dry air through the melt. He found that almost complete removal of aluminium could be achieved with no appreciable reduction in the content of either tin or zinc.

An entirely different approach to the problem of pressure tightness has been made by Johnson, Bishop and Pallini,[39] who found that pressure tightness cannot be assured with the degree of directional solidification which is to be expected in the average casting. It is only when relatively strong directional solidification is developed that the goal is achieved, and to this end the judicious use of chills is recommended.

Some Foundry Alloys.

Two patents concerned with the production of copper-lead bearing alloys have appeared. One of these[40] claims that the addition of calcium to such alloys improves the distribution of the lead and refines the grain, while the other[41] advocates heat treatment, either in the cast condition or after cold working, with the object of forming an interlaced network of copper and lead

Pelzel[42] has described the addition of silicon to cast brasses containing 60–50% of copper, and finds it to be beneficial. The silicon brasses, which are widely used in America and elsewhere for gravity die casting, normally contain much higher proportions of copper.

Commenting on a paper by Reichenecker,[43] Pfeil[44] in a recent lecture pointed out that the substitution of 2% of nickel for an equal quantity of tin in 85 : 5 : 5 : 5 gunmetal diminishes the effect of thickness on the mechanical properties of the cast material.

Calcium boride is used quite widely as a deoxidant for high conductivity copper, especially in the production of sand castings. It appears that two varieties of calcium boride are obtainable, one of which is white and the other black. According to Roast[45] the black crystalline type with the formula CaB_6 is an effective deoxidant for copper, whereas the white modification is valueless for the purpose.

A paper presented by Foulon and de Sy at the 1953 International Foundry Congress[46] serves as a timely reminder that up to 3% of copper is a valuable addition to grey cast irons.

Fabrication

General.

The O.E.E.C. report on non-ferrous heavy metal fabrication in the U.S.A.[47] must be regarded as one of the most important documents which the industry has produced in recent years. Its 250 pages are literally packed with facts and figures, and seven of the eleven chapters deal specifically with copper and copper alloys. The attention of readers is directed to an excellent summary of the report prepared by the leader of the team.[48]

The 1954 Spring symposium of the Institute of Metals was devoted to the control of quality in metal-working operations. While only two of the five papers, those by Kee[49] on hot and cold rolling, and by Smith and Swindells[50] on the extrusion process, dealt specifically with copper-base materials, two others, on the control of dimensions, shape and finish in rolling and drawing[51] and on statistical methods[52] are also relevant.

Rolling.

Cook and Parker[53] have proposed modified methods for the computation of loads in strip rolling, based on dimensional analysis. These enable results obtained with limited experimental work to be applied to more general conditions. Methods for the control of strip thickness by automatic adjustment of existing mill screws have been devised by Sims and Briggs,[54] while Allen[55] has described the use of a Sendzimir mill for the production of thin copper strip. Reductions range from 90 to 95% without annealing, and the finished strip is said to be of excellent surface quality.

A detailed discussion of modern American practice in the cold rolling of 63 : 37 brass has been published by Emicke and Lucas.[56] From the available data they have constructed graphs and nomograms for the determination of mill size, speed and power requirements. A new mill for the production of steel strip clad with copper, or with gilding metal for bullet envelopes, has been installed in America.[57]

Wire Drawing.

A symposium held by the Australian Institute of Metals comprises seven papers on the theory and practice of wire drawing.[58] Two of these, by Hoggart, deal with the effect of the temperature attained during drawing on the mechanical properties of copper wire. The tests suggested that the most satisfactory procedure would be to use a soap emulsion with high drawing speeds and light individual reductions, the object being to keep the temperature low. Williams[59] also recommends soap solutions as lubricants for the drawing of copper wires.

At another meeting of the Australian Institute of Metals, a paper was presented comparing rod rolling practice for copper with that for steel.[60] The authors express the opinion that many of the practices and details of design of the steel mill could be advantageously to the applied copper mill, especially if the latter were made to work continuously.

An account has been given of a new "gravity die block" for drawing all kinds of wire, including copper.[61] The principle is to draw the preliminary stages at higher speed than is possible on normal continuous machines, to eliminate all expensive equipment necessary to synchronise elongations between blocks, and to produce the finishing stages at a speed designed to improve the quality of the product.

In the production of enamelled copper wire, surface quality is of supreme importance. Moher[62] has enumerated some of the steps normally taken by the Canadian General Electric Company, to avoid defects, with special reference to the shaving process. A practical account of the enamelling of copper wire for electrical purposes has been published by Bliss[63], who has also discussed the factors to be considered in deriving correct wire tensions in the spooling of enamelled wire.[64]

Tube Production.

Many modern applications call for long lengths of copper and copper alloy tubes with comparatively thin walls. A new type of horizontal bull block for the drawing of seamless tubes has recently been described,[65] while two methods of making seamed tubes have also been announced. One of these[66] covers the production of tube from helically wound strip, using both internal and external welds, either or both of which may be autogenous. The process lends itself to the fabrication of bimetal tubes, copper and cupro-nickel being among the materials specifically mentioned. In the second process,[67] which is fully automatic, the strip is fed by rollers through a forming die, so that the edges butt together, and a twin electrode argon arc torch is used to effect the single longitudinal weld. Thin walled tube of tough pitch copper has been produced in this manner.

Cold Flow Turning.

Since the war years, a process of metal forming known by the above name has been introduced.[68] In essence it resembles spinning, the main innovation being the use of rollers pressing upon the work from diametrically opposite positions to eliminate the heavy thrust which would otherwise be applied to the mandrel and spindle when dealing with thick metals. Reductions of wall thickness in the neighbourhood of 80% have been achieved in a single pass, and by suitable manipulation local variations of thickness may be achieved.

Deep Drawing and Pressing.

As most readers will be aware, Professor H. W. Swift of Sheffield University has for many years directed researches on the deep drawing of metals. This voluminous work has now been condensed by Willis[69] into a book of 134 pages. The publication can be commended to all technicians concerned with practical deep drawing operations.

Extrusion.

According to Albers,[70] developments are well in hand for the extrusion of tapered and stepped sections, while, in Germany, an installation for the mains-frequency

induction heating of cylindrical billets of brass and copper, presumably for extrusion or hot pressing, has been described.[71]

Finishing and Plating

Electrodeposition.

In recent years interest has been displayed in the electrodeposition of copper from baths other than those based on the sulphate or cyanide of the metal. One which has attracted considerable attention contains copper fluoborate. Thomas[72] reports that the use of this solution in industrial electrotyping has reduced the plating time from 120 to 40 minutes. According to Colner, Feinleib and Reding,[73] the fluoborate solution is suitable for plating copper upon titanium, after a strike in cyanide, while Balachandra[74] has applied similar methods to the deposition of copper-tin alloys. A new bronze plating process has been developed by the Battelle Memorial Institute,[75] who claim that alloys of different composition and hardness can be deposited at will. In contrast, Compton and Ehrhardt[76] describe experiments leading towards the development of brass plating techniques giving the minimum variation of composition with changes of current density. Char and Shivaraman[77] have examined the electrodeposition of copper from a monoethanolamine bath as a substitute for cyanide, and report successful results.

An unusual technique of electrodepositing copper and other alloys, particularly those including gold, silver and nickel, has been announced by Gardam and Tidswell.[78] The composition of the bath is so arranged that one constituent metal is preferentially deposited, but rapidly exhausted, from the cathode film. By applying a pulsed D.C. current, all the preferentially deposited metal is removed from the cathode film at each pulse, together with some of the second metal. During the rest period between pulses the original conditions are restored by ionic diffusion. Control of the ratio of the metals deposited is effected by adjusting the frequency and duration of the pulsations.

Another new development is the production of porous metal by electrodeposition.[79] By adding colloidal graphite to the bath, together with gelatin, coherent deposits of copper or other metals can be obtained with at least 50% porosity. In contrast, Rushbrook[80] covers the difficulties encountered in the electroplating of porous articles. Mention should be made of a paper by Ollard[81] on the production of printing rollers by electrodeposition, and of a review of the many applications of electrodeposition in the printing trades.[82]

Chemical Polishing.

In the course of a review of the literature of chemical polishing, Pinner[83, 84] referred to a new technique using dilute solutions of phosphoric, nitric and hydrochloric acids with certain unspecified addition agents. It is said to be applicable to copper and copper alloys. German investigators are also interested in this subject, and two papers by Spahn[85, 86] have appeared. He describes work on the chemical polishing of copper, brass and nickel silver in various mixtures of strong acids.

Chemical Coating.

According to a German patent[87] dense, strong coatings of copper, antimony or silver can be formed on aluminium at ordinary temperatures by dipping in an alcoholic solution of ferric chloride together with a salt of the desired coating metal. Such procedure is claimed to be suitable for the production of copper coated plates for the offset printing process.

An American organisation is now exploiting the technique of depositing metal coatings by the thermal decomposition of such compounds as metal carbonyls.[88] It appears that not only nickel but also copper among other metals can be deposited in this way.

Properties and Applications

Mechanical Properties.

Carreker and Hibbard[89] have published an extensive series of tensile stress-strain curves for high purity copper. It is well known that copper weakens as the temperature is raised, but it is less widely appreciated that the properties improve at low temperatures to the extent indicated by these experiments.

Somewhat similar is the work of Halstead, McCaughley and Marcus[90] on the properties of copper and several α-brasses. Like Carreker and Hibbard, they determined true stress-strain curves and emphasised the fact, which is already appreciated widely, that the often-quoted power function of strain hardening does not apply.

Creep tests on copper at ordinary temperature have been carried out by Lushey and McKeown[91] and by Lubahn.[92] The work of Lushey and McKeown was directed towards the establishment of safe working pressures in copper tubes: they found that stresses up to 30% of the tensile strength should be permissible in annealed copper and up to 80% for cold worked material. Kennedy[93] has studied the creep of copper under pulsating stress, while Port and Blank[94] have examined the creep properties of a series of iron-bearing cupro-nickels of the type used for marine condensers and trunking. A marked benefit was obtained by slightly increasing the iron content.

The creep properties of fifteen precipitation hardening alloys based on 6–7% aluminium bronze have been studied by Dennison.[95] Alloys containing cobalt, iron or chromium fractured early, whereas those containing titanium or zirconium gave longer lives with greater elongations before fracture.

A mysterious type of intercrystalline weakness found occasionally in β-brasses has been reported by Bailey, Morris and Wiesiolek.[96] A great deal of painstaking effort was made to find, or even to suggest, a cause for the phenomenon, not only by the authors but also by Samuels,[97] but up to the present no success has been achieved.

New Materials.

Several comparatively new alloys have been announced, mainly from industrial sources. For example the Beryllium Corporation is now marketing a grade of beryllium copper containing 1% instead of the more usual 2% beryllium.[98] It combines high strength with greater conductivity than that of the normal material. Again, a paper by Llewelyn[99] outlines the development of a new bearing alloy consisting of 30% copper, 30% silver, and 40% lead, while Meyer[100] proposes two new nickel bronzes for resistance to corrosion and wear.

It has long been known that among the binary copper-manganese alloys are some which are characterised by abnormally high damping capacity. There is a suggestion that such features could be exploited in the manufacture of musical instruments.[101] It would appear that certain compositions in the copper-manganese-tin series are

almost white and take a high finish.[102] They might be of practical value in the fields of ornamental metal work and in the electrical industry.

A new patent[103] covers the addition of cobalt in amounts ranging from 1·5 to 2·5% to cupro-nickels for electrical resistance purposes, while another[104] defines copper-nickel-zinc alloys with additions of cadmium. The object of this invention is to improve the resistance to atmospheric tarnishing. Sheets of copper sandwiched between Nimonic are now available commercially,[105] to combine high thermal conductivity with resistance to oxidation at elevated temperatures.

Studies of Constitution.

Space forbids more than brief mention of a number of publications dealing with the constitution of various alloy systems. New work on the binary alloys of copper with aluminium,[106–108] beryllium,[109] boron,[110] germanium,[111] gold,[112] indium,[113] manganese,[114] silicon,[115] and titanium,[116] has become available, while ternary systems investigated include those of the copper-zinc-gallium,[117] copper-manganese-silicon,[118] copper-nickel-palladium,[119] copper-silver-indium[120] and copper-silicon-iron[121] alloys.

Copper-Lead Bearings.

Some comparative tests[122] on two grades of copper-lead and a tin-base white metal in the big-end bearings of a private car have shown that white metal evinces less tendency to retain abrasive particles of foreign substances in its surface layers. Similar service trials of copper-lead bearings plated with pure tin, lead-tin and lead-indium indicated that the retention of foreign particles could be almost completely suppressed by this expedient.

Corrosion

Copper Sewage Pipes.

Babbitt, Baumann and Hayward[123] have reported a series of experiments extending over five years on the corrosion of copper pipes carrying sewage. The corrosive attack was distributed fairly uniformly over the exposed surfaces, reaching a depth of approximately 0·01 in. in the five years of test. No seriously localised corrosion or pitting was reported. The addition of detergents to the sewage had no effect on the corrosion.

Galvanic Action between Copper and Cast Iron.

Under conditions of galvanic corrosion, copper is normally cathodic to iron, and tends to be protected by the sacrificial corrosion of the latter. Higgins,[124] however, noted that copper was sometimes preferentially attacked when coupled with graphitic cast iron. An investigation of this phenomenon indicated that it occurred after the iron had been corroded away from the surface layers, leaving graphite which is cathodic to copper.

Marine Corrosion.

Kenworthy[125] and Gilbert,[126] both recognised authorities on marine corrosion, have independently discussed problems concerned with the use of copper-base alloys at sea. Kenworthy mentions that cast aluminium bronze, cast phosphor bronze and beryllium copper are liable to suffer penetrative attack in superheated steam under certain conditions, and advises caution in the use of such materials for steam service, while Gilbert stresses the importance, particularly with aluminium brass tubes, of not allowing polluted waters to remain in the condenser for any appreciable length of time during its early life.

Cavitation and Fretting.

Cavitation erosion has been examined by Schaefer, Cerness and Thomas[127] from the point of view of its effect on metals used for bearings. Among the materials which showed promise for use at high speeds, frequencies and temperatures, was a cast leaded bronze.

Godfrey and Bailey[128] have studied the initial stages of fretting corrosion on copper, when rubbing against glass, steel, and other copper surfaces. They conclude that fretting of copper starts with the same type of mechanical damage that occurs during unidirectional sliding.

Joining

Arc Welding.

Two recent papers, by Winterton[129] and by Davis and Terry,[130] respectively, describe experiments on the nitrogen arc welding of copper-base materials. Both emphasise the need for gas of high purity, especially in respect of oxygen and moisture, and given these conditions, both report success.

The metallic arc welding of copper, without gas shield, has also received attention, and good results have been reported on high conductivity copper, using specially coated consumable electrodes of the same material.[131] A paper of Russian origin[132] describes the use of phosphor bronze filler rods for the arc welding of copper.

Brazing.

Two papers which are somewhat similar in nature describe brazing alloys for electronic components[133] and for stainless steels,[134] respectively. In both cases most of the recommended alloys contain copper.

According to Chatfield,[135] the presence of minute traces of aluminium in silver brazing alloys may destroy their adherence to steel. Even brazing alloys which are initially quite free from aluminium can give this kind of trouble if used for joining either aluminium bronze or aluminium brass to steel, because of contamination with aluminium dissolved from the parent metal. The author states that the addition of nickel to the brazing alloy is beneficial.

Cold Pressure Welding.

Both Hughes[136] and Tylecote[137] have contributed to the study of cold pressure welding. The authors agree that such welds can be made not only between two pieces of copper but also between copper and other metals such as aluminium, iron or nickel. To obtain strong joints, however, local deformations of from 70 to 90% are necessary, and high pressures are consequently required.

Powder Metallurgy

Wrought Products from Powder.

Growing interest in the production of wrought products, such as rod and strip, from powders stems from the probability that copper powder, prepared chemically from ore or scrap may become commercially available in bulk in the not too distant future. Franssen,[138] in Germany, has reviewed the technical and patent literature of the subject, while Jones[139, 140] has made comparable publications in this country. Franssen visualises an integrated plant for the preparation of powder and

thence to strip, while a development reported by Jones is the manufacture of semi-finished products by powder spraying. Steinitz, Scanlan and Zaleski[141] have described the formation of sintered cups to be drawn into cartridge cases by conventional means. The material they used was iron, but similar techniques could undoubtedly be applied to copper and its alloys.

Centrifugal Compacting.

According to Lindberg[142] a centrifugal technique of compacting metal powders, appears promising, especially for the production of parts too large to be compressed conveniently by normal methods. The principle could possibly be applied to the bulk production of flat products from powder, by centrifuging a ring which could be opened out and rolled after sintering, much as in the Soro process of casting.

Monel from Powder.

Benesovsky[143] states that 70 : 30 nickel-copper containing iron and manganese prepared by powder metallurgy shows resistance to corrosion equal to that of a conventionally produced Monel.

Physical Metallurgy

Physical Properties.

Recent studies of the physical properties of copper include two determinations of the vapour pressure over a considerable range of temperature,[144, 145] and one of the thermal and electrical conductivity at low temperatures.[146]

The most obvious effect upon metals of plastic deformation is the alteration of mechanical properties which it brings about. It also has, however, an important influence on such physical properties as electrical resistivity. Linde,[147] studying copper base alloys among other materials, has proposed an equation expressing the change in resistivity as a function of time and temperature during subsequent "recovery." From somewhat similar work on copper at sub-zero temperatures, Pry and Hennig[148] conclude that the residual electrical resistivity, after recovery at room temperature, is directly connected with the stress necessary to continue plastic deformation in tension.

The relationship between the specific heat of silver-bearing copper and plastic deformation has been examined by Stansbury, Elder and Picklesimer.[149] A reduction in area of 85% increased the specific heat by 0·9 cal./gm., and the release of this stored energy was roughly coincident with the recrystallisation temperature.

The Mechanism of Fatigue.

Bullen, Head and Wood[150] have shown that when copper is subjected to static stress or to slowly alternating stress cycles, the grains break down into disoriented elements. Under rapidly alternating stress, however, the breakdown does not occur, and the strain produced is highly localised. Franz[151] has found that small repeated prestrains have no effect on the total ductility of annealed high conductivity copper, and work by Welber and Webeler[152] seems to suggest that fatigued copper has no increase in internal energy, rather the reverse. Breen and Lane[153] have carried out tensile-fatigue and stress-rupture tests on α-brass between 290° and 540° C., and at room temperature, with special reference to the effects of grain size.

Intergranular Stress-Cracking.

Greenwood, Miller and Suiter[154] have described the formation of minute cavities at the grain boundaries of copper and brass, among other metals, under the prolonged application of stress. These lead to the development of intercrystalline cracks, and ultimately to rupture. The authors describe the probable mechanism of the process.

Miscellaneous

Increasing interest has lately been evinced in heat pumps, not only for public applications but also for domestic use.[155-157] Copper piping and copper alloy fittings are likely to be required in this connection. Printed circuits also call for considerable quantities of copper, especially in the form of thin foil,[158, 159] while organic compounds of copper are claimed to be of value in the production of office carbon paper.[160]

Search for new materials for use in transistors is being actively pressed by the radio industry, and a brief note[161] suggests that certain copper compounds show promise in this connection. Reference is made to the "chalcopyrite type of materials," and copper indium selenide is specifically mentioned.

Cook[162] has written an account of progress in the non-ferrous industries during the past 50 years, while Spengler[163] has brought up to date the well-known bibliographies on alloy systems compiled by Haughton, the last of which appeared a decade ago.

A book on brass, characterised by German thoroughness, has been issued by the Deutsches Kupfer Institut.[164] Sara Davenport[165] has reviewed the literature of the effects of copper on health. Hutton[166] has summarised the general conclusions to be drawn from the reports of 66 productivity teams visiting America.

This survey would be incomplete without reference to the most comprehensive publication on copper as yet produced, namely that edited by Allison Butts for the American Chemical Society.[167] Its 46 chapters, each written by an expert, are packed with authoritative information on the metallurgy and use of the red metal.

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Thorncliffe-Built Tilting Furnace Bodies

THE first of a number of 250/350-ton tilting type steel furnace bodies to be built by the Heavy Construction Department of Newton Chambers & Co., Ltd., to the order of the Wellman Smith Owen Engineering Corporation was recently completely assembled in the constructional shop at Thorncliffe to ensure a good fit when finally erected. This operation called for considerable ingenuity in view of the space required, the furnace being 51 ft. 6 in. long, 29 ft. wide, and, excluding the rockers and bearer girders, 22 ft. high.

Two of these furnaces are to be erected by Newton Chambers at the Irlam Works of Lancashire Steel Corporation, and a further three are to be shipped to the new steelworks at Aviles in Spain. Besides the furnaces, two 600-ton mixers are to be built, one for Irlam and one for Aviles. In all about 1,600 tons of fabricated steelwork is involved.

Correspondence

DRIP FEED GAS CARBURISING

The Editor, METALLURGIA.

Sir,

We should like to express our agreement with the opinions expressed in the letter from Messrs. Integra, Leeds, and Northrup, Ltd., which was published in the Correspondence Column of your December issue, concerning a recent article on "Drip Feed Gas Carburising."

In 1948 we introduced the "Positive Injection Method" to obtain improved delivery regulation of the fluid to a gas carburising furnace by comparison with "drip feed," and at the same time introduced "Lithanol," a lithium-bearing fluid which, under comparative tests, has been demonstrated to have certain advantages.

We believe that more British furnace builders will soon accept hydrocarbon fluid as the basis of reliable gas carburising, no matter how they may decide to feed the fluid to the system.

Yours faithfully,
for the Incandescent Heat Co., Ltd.,
J. A. Swain,
Sales Manager,
Smethwick, Birmingham. 3rd January, 1955.

Recent Progress in Alloy and Special Steels

By G. T. Harris, M.A., F.Inst.P., F.I.M., and E. Johnson, A.Met., A.I.M.
Research Department, William Jessop and Sons, Ltd.

Although revolutionary developments such as the introduction of the Bessemer process do not happen every year, progress in ferrous metallurgy continues. Apart from advances in production techniques, there have been a number of interesting developments in the alloy and special steel field which are the outcome of collaboration between workers in the steel industry and those in the steel consuming industries.

DEVELOPMENTS are continually taking place in alloy and special steels, as they are in any live technical industry. It is usual to find that in most directions there is a steady improvement in alloys, processing and our understanding of the scientific background, whilst in a few directions there are more sudden and spectacular advances. This review covers both types of advance over the past year or two, drawing attention to some of the important papers published and summarising the general trends in the field of constructional steels, tool steels, and corrosion- and heat-resisting steels.

Constructional Steels

In the period under review, say the last 18 months or so, further advances have been made in the development and use of the so-called high strength, low alloy structural steels. The strength of these steels, on the basis of the yield-strength, is about 50% greater than that of structural mild steel. The atmospheric corrosion resistance of some of them is a good deal higher also, and in general their weldability, notch toughness, and workability characteristics are as good as, and indeed often better than mild steel. A wide variety of such steels is available and a recent survey[1] gives trade names, with mechanical properties (including fatigue) and welding characteristics of steels of this type from many countries. A number of suitable alloying elements are available and these steels usually include two or three from the following: manganese, copper, silicon, chromium, nickel, molybdenum, phosphorus and boron.

A number of developments are taking place in which vanadium additions are being made. In a paper[2] on the continuation of research on high strength, low alloy structural steels by the British Welding Research Association, details are given of the effect of replacing some of the molybdenum by vanadium in two of the steels previously developed by the Association. The improved strength and impact values, at both room and low temperatures, of the vanadium-containing steels is attributed to their fine-grained structures; the composition of one of these steels is: 0·15% carbon, 0·78% manganese, 0·73% nickel, 0·92% chromium, and 0·14% vanadium.

Investigations by Nehl[3] and Cottrell[4] have made use of austenite transformation data in order to study the influence of composition and other variables on the characteristics of high strength structural steels during welding.

In the field of the fully heat treated steels, due to an easing in the supply position of certain alloying elements, a wider use has been possible of certain En. types. The popularity of certain of the emergency case-hardening steels (Addendum No. 1 of B.S. 970) continues, and certain economies by virtue of the lower alloy contents are, therefore, still being made. When suitably heat treated, these economy steels are entirely satisfactory. Recently three new specifications have been added to the B.S. Aircraft Series, viz., S.118 (55-ton), S.119 (65-ton) and S.120 (100-ton). It should also be mentioned in connection with alloy steels, particularly those for aircraft construction, that they are now produced under the conditions of inspection laid down by B.S. 2 S.100. Though many steelmakers were already carrying out a similar but more limited inspection, the requirements of this specification, together with certain others, have necessitated an expansion of inspection facilities in steel works, thus adding appreciably to the reliability and high quality of such steels.

No discussion on constructional steels could be complete without reference to the large amount of work that is going on, both here and abroad, on the low temperature properties. Not only has this work practical value, but it draws attention to the transition-impact characteristics and the significance of an impact test at room temperature. Outstanding is the work of the N.P.L. on a general programme on the influence of alloying elements on the mechanical properties of pure iron, and in a recent paper[5] the effects of a number of elements on the tensile and impact properties over a range of temperatures have been studied. Such work is fundamental to the understanding of the effect of elements in steel, and the technical properties of commercial steels, particularly in relation to brittle fracture.

Extra-High-Tensile Steels

It has been said that the theme of ferrous metallurgy requirements and developments of the last 15 years has been sung by the aircraft industry, and a fresh example is given by the latest demands in constructional and engineering steels. There is a growing interest in air-frame and undercarriage parts in a steel having extra-high strength with adequate toughness, giving favourable strength/weight ratios and other characteristics. The minimum mechanical properties stated to be of interest in a typical aircraft requirement are :—

0·1% Proof Stress	85 tons/sq. in.
Ultimate Tensile Stress	120 tons/sq. in.
Elongation on 2 in.	6%
Izod Impact	20 ft.-lb.
Izod Impact at −50° C. ..	10 ft.-lb.

TABLE I.—PROPERTIES OF SOME HIGH STRENGTH STEELS.

Quality	Equivalent En Specification	0·1% Proof Stress tons/sq. in.	Ultimate Tensile Strength tons/sq. in.	Elongation %	Reduction of Area %	Impact (Izod) ft.-lb.
G.8	En.27	82	110	14	48	31
G.11	En.25	81	102	14	50	24
G.5 Spl.	En.24	88	126	12	35	20
H.27	En.40C	84	118	14	40	30
R.D.M. 682		100	125	12·5	37	16
G.1 Spl.	En.30B	78	112	14	47	42

It has long been known, of course, that at low temperatures of tempering, some steels possess very high tensile strengths, and the failure to make use of these has, in the main, been due to the feeling that such steels are in a highly stressed and brittle condition.

A recent report,[6] from which the details of Table I have been taken, suggests that certain steels, suitably heat treated, have attractive properties. The work is continuing, but it will be noted that certain compositions such as that of R.D.M. 682 (Table I) give 0·1% proof stresses of 100 tons/sq. in. with impacts of 16 ft.-lb., and though others give higher impact strengths the proof stresses are lower. In between these extremes En.24 (G.5 Spl.) meets the stated requirements as above. As with all materials when the highest potential characteristics are being exploited, it is necessary to watch carefully the manufacturing techniques and the design. It is obvious that embrittlement due to plating, etc., must be removed or relieved, and that sharp-notch damage due to bad grinding and other undesirable features should not occur in the part. These, and other aspects of the development and use in America of these extra-high-strength steels, have been discussed in various papers.[7, 8, 9] One of these papers reports that experimental studies indicate that if the quenched parts are sub-zero treated in liquid nitrogen, the tensile properties at room temperature are improved without much change in the ductility figures. Long tempering treatments have also been recommended. The machining of these steels must be finished as far as possible before heat treatment, as they are difficult to machine when hardened, even with modern tools. The stress-corrosion properties and the fatigue strength of steels of this type will need full investigation, however, before the engineer can accept them without reserve.

Cold Work Tool Steels

For many cold working applications such as blanking, pressing, punching, etc., the well-known ranges of tool and die steels can be said to be adequate for most production runs, and development of new types has not received much attention until quite recently. With the growing use of cold extrusion, especially for steel parts, and of thread rolling, new demands have arisen. Not only are high compressive strength and wear resistance needed, but toughness (i.e., freedom from chipping tendencies) must be adequate. For the punch in cold pressing operations, high speed steels based on tungsten and on molybdenum, but having a lower carbon content than usual, are being used with success. High carbon, high chromium steels with molybdenum and vanadium additions are also recommended, especially for thread rolling. As these and other applications of cold working steels grow in importance, further developments in this field can be expected, as there is still a gap to be filled between tool steels and cemented carbides. These and other aspects of such materials were discussed in a paper[10] presented at a conference in London in 1953 on the cold extrusion of steel.

There is an increased use of cold hobbing of plastic moulds in which the steel mould is carburised after hobbing. A recently developed steel for large moulds is H.49, which has 5% chromium and a very low content of carbon and other elements, so that it is comparatively soft when annealed for hobbing, but after carburising it can easily be heat treated to give a high surface hardness, good core properties, and low distortion.

Hot Work Tool Steels

For the extrusion, forging, pressure die casting, etc. of metals, a wide variety of hot work steels is available: some, in fact, are quite new and their full capabilities are not yet known. For the extrusion of non-ferrous metals, the dies are generally made of steels such as the 10% tungsten, 5% chromium-molybdenum-tungsten, 5% chromium-molybdenum-vanadium, and 6% tungsten-nickel-chromium types. When extruding copper alloys, however, the conditions of service involve more severe temperatures and abrasion, and a steel containing 12% tungsten–12% chromium (WEX 609) and a cobalt-base creep resisting alloy (G. 32) have given good results. The use of a creep resisting alloy as a hot work material is an interesting though logical development.

Precision forging operations, such as in the manufacture of turbine blades in titanium, bronze, and stainless steels, are making great demands on the materials used for the dies or die inserts. The 5% chromium-molybdenum-vanadium steel (H. 50) has been proved to be the best, and in a paper given to the Fourth Technical Convention of the National Association of Drop Forgers and Stampers held last November,[11] the properties were discussed of this and other special steels for dies and tools.

High Speed Tool Steels

In previous reviews in METALLURGIA,[12, 13] mention was made of the high wear resistant types of high speed steel. Two of these, details of which are given in Table II, have become increasingly popular and J.36, the latest development, is giving good results as tool bits and milling cutters; for many applications it is superior to the conventional 10% cobalt, 20% tungsten types. There are difficulties, such as problems in heat treatment and final grinding of this steel, but where the cutting conditions are severe, and hence a super high speed steel is required, it is an attractive choice. Other new high speed steels are in the "customer trials" stage of development.

One problem that is being tackled energetically is the reduction in friction between the high speed steel and the workpiece. A step in this direction is the use of steam tempering, which is being used to an increasing extent for drills and similar components. After the tools

TABLE II.—HIGH SPEED STEELS CONTAINING HIGH VANADIUM

	J.13	J.36
Composition		
Carbon %	1·25	1·50
Chromium %	4·6	4·7
Tungsten %	13·5	12·5
Vanadium %	3·75	5·0
Cobalt %	—	5·0
Heat Treatment		
Oil Quench	1,270° C.	1,250° C.
Double Temper	550° C.	550° C.

have been hardened, tempered, and ground, they are loaded into a steam atmosphere at about 350° C., and after one hour of such treatment gradually brought up to a temperature of 550° C. with the steam turned off. The tools then have a blue finish, and it is this surface which has the anti-friction properties. Whether such a finish is better than certain proprietary chemical finishes has yet to be finally proved, but steam tempered drills are certainly better than those having no surface treatment. Another treatment in which the surface layers of the tools are sulphurised in a salt bath has been described: [14,15] increased lives of taps and drills are claimed.

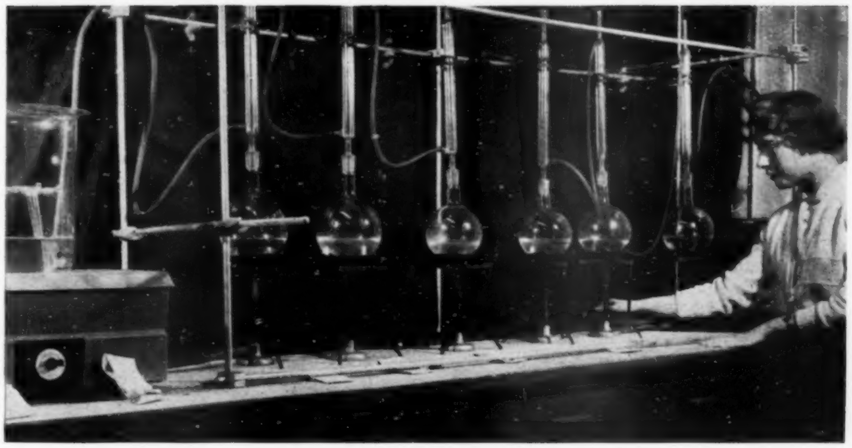

Fig. 1.—Part of corrosion testing laboratory.

It is claimed in the United States[16] that high speed steels containing about 0·12% sulphur have superior properties, and are giving excellent service as gear hobs and in a number of other difficult machining operations. Not only is the making of tools facilitated by the free machining properties of the steel, but the finished tools have a longer life due to the lubricating effect at the cutting edge of the sulphur content. The toughness of the tools is alleged not to be affected by this addition.

Heat Treatment of Steels

So far, the emphasis of this review has been concentrated on modifications and new compositions which have been developed to give improved properties. In the period concerned, however, the co-partner of composition—heat treatment—has not failed to receive attention. Not only have improvements in apparatus such as furnaces and ancillary equipment taken place, but a greater understanding has been reached of the fundamentals of heat treatment. One factor responsible for this was the Conference on Heat Treatment Practice organised by the British Iron and Steel Research Association at Ashorne Hill last year. Among the subjects of practical as well as theoretical interest covered by the speakers, was a review of the work of the Thermal Treatment Committee and the Isothermal Transformation and Hardenability Group of that organisation. A recent publication[17] gives in tabular form the results of work sponsored by the Committee at the National Physical Laboratory on the physical constants of steels at room and elevated temperatures. This has been found extremely valuable to those concerned with the heat treatment of alloy steels. A new " Atlas of S-Curves " is being prepared by the Group which should be of great value, as should other work which is stated to be in hand.[18]

Considerable further contributions have been made recently to our knowledge of the phenomenon of temper brittleness in alloy steels. Two papers, one British[19] and one American,[20] describe the effect of chemical composition studied by the testing of steels of high purity. Another British paper[21] studies the influence of arsenic and antimony on the embrittling process, and Woodfine in a critical review[22] surveys the published work up to 1952. The same author reports[23] the results of experimental studies, and concludes that temper brittleness is not the result of a simple precipitation of compounds from solution in the ferrite. He suggests that it can be explained by the segregation of solute atoms to the grain boundaries in both the austenite and the ferrite.

In connection with surface hardening processes, an increasing use is being made in this country of such processes as gas carburising and carbo-nitriding, and this has been followed up in the practical sphere by a number of furnace makers who have developed equipment capable of maintaining satisfactorily the critical gas environment.

Corrosion Resisting Steels

Many and great demands have been recently made by the chemical and petroleum industries, atomic energy plants, and others, for corrosion resistant steels. The wide range of well-known stainless steels has been satisfactory for most purposes. A highly corrosion resistant austenitic alloy containing copper and molybdenum continues to be of considerable use in the cast condition, and recent developments have suggested that a forgeable material of this type can be produced. Part of a laboratory used for corrosion studies is shown in Fig. 1.

Substitute stainless steels containing 17% chromium are well known, and recently certain chromium-manganese stainless steels have been described.[24] If a fully austenitic structure is required, using manganese and chromium alone, then the manganese content must be at least 13% if the percentage of chromium is 13. However, alloys containing 18% chromium with manganese in the range 6–14%, can be rendered austenitic by the addition of 0·1–0·15% nitrogen and 2–6% nickel. One grade in regular commercial production in the United States contains 15% chromium, 16·5% manganese, 1% nickel, 0·15% nitrogen and 0·1% carbon. Its properties are similar to 18–8 grades in most respects.

The hardening of stainless steel has also received a considerable amount of attention. A number of such steels containing small amounts of some of the elements aluminium, titanium, copper, niobium, and beryllium, can be suitably precipitation-hardened to give mechanical

properties comparable with those of heat treated constructional steels, combined with a good corrosion resistance.[25] In severe conditions these alloys show, however, that their corrosion resistance has been somewhat impaired by the additions and heat treatment, and they are also not completely non-magnetic.

The precipitation hardening of 21–12 Cr-Ni types containing 0·5% carbon and 0·3% phosphorus, has been studied,[26] and another patented composition[27] relies on the precipitation effects of balanced compositions with additions of aluminium, copper and silicon.

The work hardening characteristics of austenitic stainless steels have been investigated by a number of workers. Cina[28] has studied the effect of cold work on the *gamma-alpha* transformation in some Fe-Ni-Cr alloys, and a French patent[29] covers the addition of copper up to 4% to prevent breakdown of the austenite during cold work. Another patent[30] covers the hardening of austenitic Cr-Ni steels by working at sub-zero temperatures, after which very interesting mechanical properties are reported.

No review of stainless steels would be complete without mention of the extra-low-carbon grades with their good resistance to weld decay. In this country the customer demand does not appear to be as high as in the United States, but some makers have mastered the technique of the production of such steels in the arc furnace with carbon contents of 0·03% max.

Much work has been done on *sigma*-phase in stainless steels. Of the published work the review by Lena[31] is very valuable, and also of interest is a recent paper by Allten[32] describing the persistent nature of *sigma* in a steel containing 0·06% carbon, 1·26% silicon, 21·15% nickel, 18·72% chromium, 9·14% molybdenum, and 2·07% tungsten. From many aspects, the use of the hardening brought about by *sigma* formation in certain commercial steels would appear to be a logical development of much of this work, the only well-known use at present being the X.C.R. valve steel.

High Temperature Materials

The imperative demand of the jet engine designer for better high temperature materials has led to a constant substantial increase in the properties available. Hitherto, the rotating turbine blades themselves have in this country been the exclusive province of the nickel-base precipitation-hardened alloys, but there are signs that other materials may supplant them for the most severe conditions. An iron-base alloy G.42B has already run successfully in one of the most advanced jet engines, and for operating temperatures exceeding 900° C. it is one of the strongest wrought alloys yet available. The properties of this alloy are given in Table III, and it can be seen that for a life of 100 hours, which is more than adequate for fighter jets, a satisfactory working stress can be sustained at temperatures approaching 950° C. This is a figure which compares with the maximum operating temperature of the early jets at about 650° C., and demonstrates how temperatures have since that time progressed steadily at the rate of about 100° C. every four years. This latest achievement with a relatively low alloy content (15% nickel, 29% chromium, 25% cobalt, 32% iron) has been made possible by an intensive development of the process of warm-working which was used for the manufacture of tens of thousands of turbine discs in Jessop G.18B, of which G.42B is a logical development. The experience built up in controlling the warm-working of turbine discs has been utilised to ensure the uniformity of properties in blades. So far the alloy has only been used for the short-life jet engine, but already long-time creep tests up to 2,000 hours have been carried out, and the alloy may find use in the heavy gas turbine industry.

TABLE III.—STRESS-TO-RUPTURE PROPERTIES OF JESSOP G.42B BLADING ALLOY.

Temperature ° C.		750	800	850	870	900	950
Stress to Rupture (tons/sq. in.) in	30 hrs.	21·5	16·7	13·1	11·3	9·0	6·9
	100 hrs.	19·3	14·4	11·0	9·0	7·1	5·1
	300 hrs.	17·4	12·5	9·2	7·2	5·7	3·9
	1,000 hrs.	15·4	11·0	7·6	5·7	4·5	2·9

Other wrought turbine blade alloys are under development, and it is interesting to note here the increasing world interest in vacuum melting. Producers of special alloys in the United States and several firms in Europe have installed such equipment. One of the first commercial vacuum-melting installations in an English steelworks laboratory (Fig. 2) has already made hundreds of

Fig. 2.—20-lb. vacuum melting installation.

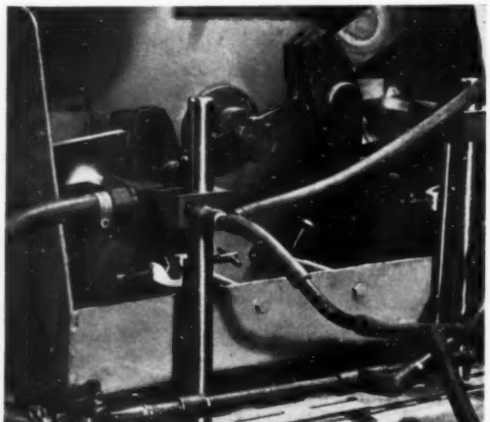

Fig. 3.—Thermal shock testing apparatus (note twin gas jets).

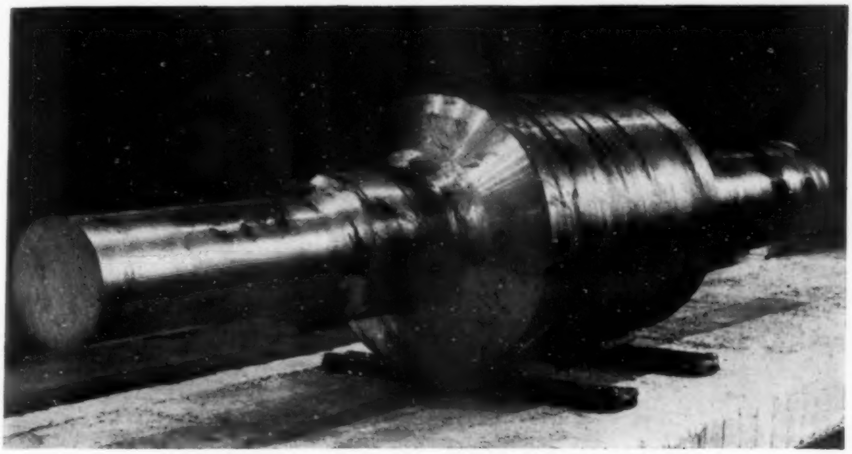

Fig. 4.—8-ton rotor (35 in. diameter) in H.46 steel.

the limiting factor, and by about 30% where fatigue is of major importance. It is important to note, however, that it is still necessary to ensure that there are no blades put into service which lie below the strength corresponding to the 3σ limit, and this implies the necessity for adequate methods of non-destructive testing which will ensure the rejection of such components. It is believed that these problems can be solved, and that there will be in this country a partial swing from wrought to cast turbine blades. A similar investigation is now being carried out in order to determine whether the scatter can be reduced by vacuum-melting and casting, and already the evidence suggests that this is so.

experimental melts, and is proving a valuable tool in alloy development. The initial cost of such equipment must be high to provide sound vacuum engineering, but once installed it is possible to make four heats a day regularly without any technical difficulties, so enabling attention to be concentrated on alloy development. This type of melting is desirable where it is necessary to investigate the effect of gases (particularly nitrogen), and the effect of trace elements, and it is essential for those cases where large quantities of highly reactive elements, such as titanium and aluminium, are employed. The problem of the determination of gases is important and is referred to later.

British gas turbine practice, for the last ten years at least, has been to use only wrought material for rotating turbine blades. This is in contrast to the American practice where precision cast blades have been used in considerable quantities. It is probably true that a part of the reliability of the British jet engines can be attributed to the freedom from blade failures, but the economic and production possibilities of precision castings are such that they cannot be ignored indefinitely in this country. A paper dealing with a statistical estimate of the scatter in high temperature properties to be expected in precision casting of a cobalt-base high temperature alloy, G.34, has recently been published.[33] It was there shown that the distribution of properties is approximately Gaussian, and the scatter ($\pm 2\sigma$) of the 300-hour rupture strength and of the fatigue strength (40 million reversals) at 750° C. have been shown to be $\pm 10\%$ and $\pm 22\%$ respectively. The practical implication of these results is that the average values of the high-temperature properties must be reduced by about 15% in the case of applications where creep is

The objections to casting do not apply in such a marked degree to their use for the stationary nozzle guide vanes where the stresses are substantially lower, and most of the British jet engines have, in fact, used cast heat resisting steel or cobalt-based alloys for these components. As engine temperatures have increased, the simpler austenitic casting alloys have been found inadequate, and stronger materials proved necessary. The latest development in this field is the use of G.39, a nickel-based high carbon casting alloy developed from G.18B. Because of the high nickel content (over 60%) the thermal expansion is low, and this reduces the thermal stresses and improves the resistance to thermal shock. This property can be measured by alternately heating and cooling a wedge-shaped specimen (Fig. 3) and determining the number of cycles necessary to cause cracking of the thin edge. Resistance to thermal shock is a complex property depending upon the thermal expansion, the thermal conductivity, and the plastic behaviour of the material under cyclic stressing over a temperature range. For this reason it is not possible to

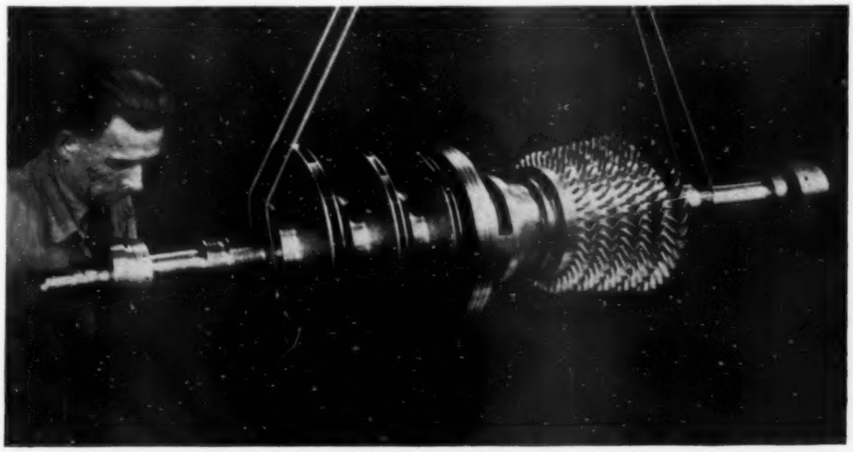

Fig. 5.—G.38 rotor with G.18B blades for Escher Wyss 2,000 kW. closed cycle power plant.

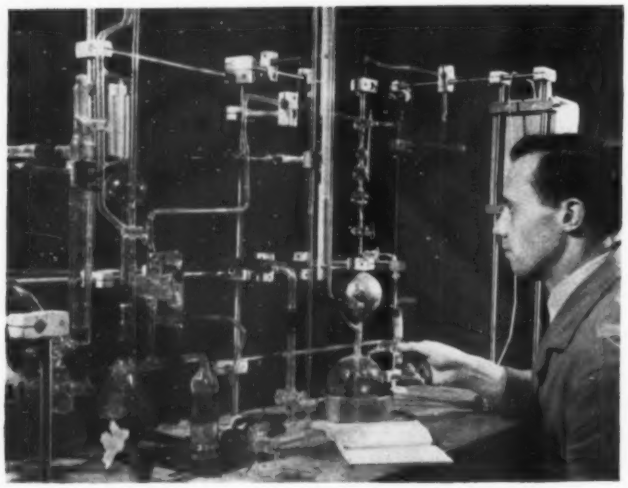

Fig. 6.—Hydrogen estimation apparatus.

determine the resistance by a simple test, but the simulated service test referred to gives a fair idea of the behaviour under engine conditions where the nozzle guide vanes take the first impact of the flame alternated with blasts of cooling air from the compressor each time the throttle is closed.

The tendency already noticed some three years ago for austenitic turbine discs to be replaced by ferritic steels has been confirmed and accentuated. It is doubtful whether any new British jet engine uses a turbine disc in a steel other than the modified 12% chromium steel represented by H.46 and 448. The high proof stress available, combined with adequate creep strength up to about 550°–600° C., enables turbine discs to be extremely thin, and it is unlikely that British designers will wish to revert to austenitic steels unless these can be produced with proof stresses exceeding 40 or 50 tons/sq. in. The Americans are using increasing quantities of 25% nickel, 14% chromium, titanium-hardened steels (Discaloy A.286) developed from the war-time German Tinidur. The proof stress obtainable exceeds 40 tons/sq. in. and the Americans are making use of the good austenitic creep strength since they do not employ the disc rim cooling now perfected by British designers. Such a steel is available in this country (G.56) but British designers do not appear anxious to make the change from the simpler and cheaper ferritic steels. Instead they prefer to increase still further their technical demands on the modified 12% chromium steels, but it is clear that substantial progress on these lines will be exceedingly difficult.

To a smaller extent the heavy gas turbine industry is tending to follow this lead to ferritic steels, and large rotors have already been supplied for stationary gas turbine plant. The largest forging yet made in one of these highly developed 12% chromium steels is 35 in. in diameter (Fig. 4) and is at present being installed in a Continental plant. There is still, however, a demand for austenitic steels, and in some turbines G.18B has been replaced by G.38—a much simpler and cheaper austenitic steel containing neither cobalt nor niobium, but having about twice the creep strength of the usual simpler austenitic steels. A rotor of this material bladed with G.18B is shown in Fig. 5.

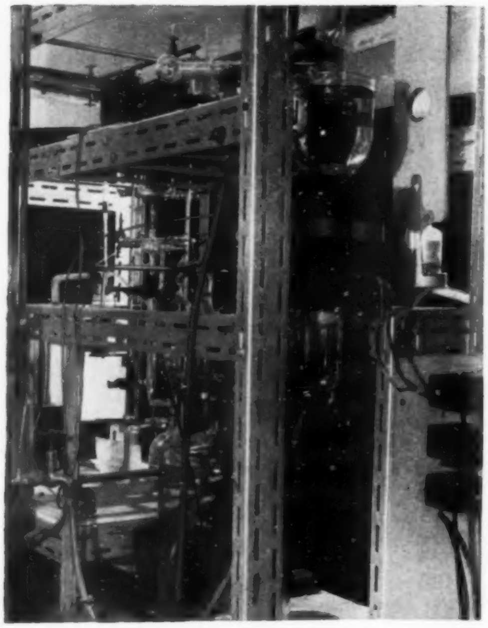

Fig. 7.—Part of apparatus for vacuum gas analysis.

Steam plant is also tending to operate at higher temperatures, and both American and German stations are now designed on steam at 1,130/1,150° F. This has involved new material problems, particularly for steam piping and superheater tubes. Some engineers have adopted the use of austenitic steels, but this change has been resisted as long as possible in view of the difficulties of welding and of thermal expansion. Steam valves, turbine casings and bolts have also required better materials, and in some cases the decision has already been taken to change to austenitic steels.

Developments in Alloy Steel Manufacturing Processes

The question of trace elements has already been mentioned, and in particular the problem of gases both as impurities and as alloying additions. One significant feature in the advance of metallurgy has been the increasing realisation of the importance of gases in metals. The serious effect of excess quantities of hydrogen in steel leading to cracking either during or subsequent to manufacture has led many steelworks to install routine hydrogen analysis apparatus, so that regular checks can be made of the hydrogen content of the more important heats, such as those intended for highly stressed forgings. Such an apparatus (Fig. 6) has been extensively used at the authors' works not only for analysis of the hydrogen in the liquid steel at the time of tapping, but also to determine the hydrogen content of steel-making constituents such as alloys and slag-making materials. This work has been of importance in defining the main causes of hydrogen pick-up, and hence the proper methods of steel-making control.

The apparatus used is relatively simple, and relies upon the ease with which hydrogen diffuses out of solid steel at quite moderate temperatures in a vacuum. A much more complex apparatus is needed to determine

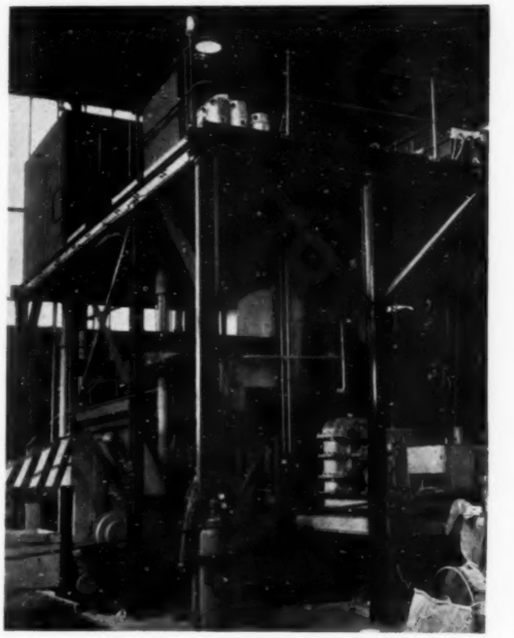

Fig. 8.—Two-strand continuous casting plant.

the oxygen content in steel, since this can only be removed by melting under vacuum. Such apparatus (Fig. 7) is being used increasingly as a routine control on steel-making technique, since it not only affords the only method for oxygen analysis, but also the most reliable for the determination of nitrogen. Chemical analysis for nitrogen is sometimes complicated by the presence of other elements, and since additions of nitrogen are regularly used in some of the more modern creep resisting steels, a reliable routine analysis method is essential.

The apparatus shown employs a 30 kW. radio frequency generator to melt the sample, and is being used to make thirty estimations per week of the oxygen and nitrogen contents of special heats. The work has demonstrated how this advanced method of trace analysis can serve to indicate the directions in which better steel-making and deoxidation practices can be followed.

The increase in production of complex alloy steels has brought its own problems in their manipulation. Further information is available[34] on the use of rare earth additions to stainless and other steels to improve working properties, etc., and this technique has just been granted a British Patent.[35] Another American development[36] involves the treatment of molten austenitic steels with magnesium metal which, it is claimed, gives a product of improved properties.

Another possible solution to the difficulties of manipulation is being tried extensively by utilising extrusion in place of the conventional forging and rolling. The practice of extrusion has grown considerably following the introduction of the French Ugine-Sejournet technique of glass lubrication, and it is now proving possible to extrude alloys which were formerly considered to be unworkable.

An important development which may have effect both on the economic production of high alloy steels and on their metallurgical quality is the application of continuous casting. Plants are now working in the United States, at Allegheny-Ludlum and Babcock & Wilcox; in Canada, at Atlas Steels; and also in Austria, Germany, and France. Three plants are known to be working in this country; one, a private development, at Low Moor Alloy Steelworks; a Rossi-type plant at the Barrow works of The United Steel Companies; and, most recently, one based on the British Iron and Steel Research Association's developments at William Jessop & Sons, Ltd. This last plant (Fig. 8) has been installed and operated on behalf of a group of 11 steel firms who have particular interests in the field of high speed and other special steels. The plant started to operate in April, 1954, and although it is too early to indicate the final outcome, it is clear from the interest both in this country and abroad, that continuous casting will play a considerable part in the future in the production of special and alloy steels.

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The Effect of Zinc in Aluminium-Silicon-Copper Casting Alloys

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In view of the need to make the best use, in the production of casting alloys, of zinc-containing aluminium scrap, an investigation was undertaken to determine the effect of higher zinc contents on alloys of the LM-4 type. Up to 3% zinc was shown to have no harmful effect on the room temperature mechanical properties.

A LARGE proportion of the raw material used in the manufacture of aluminium casting alloys occurs in the form of process scrap from the production and fabrication of wrought aluminium alloys. Consequently it is necessary for the producers of casting alloys continually to review the changing trends in wrought alloy consumption, and to assess the effect these changes will have on refining practice, and, possibly, on the composition of the resulting casting alloys. In recent years the increasing use of the high strength zinc-containing wrought aluminium alloys, e.g., D.T.D.683, has resulted in a corresponding increase in zinc-containing scrap, and some two years ago the quantities arising became sufficient to necessitate a special study of the problems of their assimilation. Discussion between the founders and ingot producers confirmed that, if practicable, this material should be used for the production of the most widely used of casting alloys, LM-4, or a closely similar alloy.

Since the adoption of this course would result in an increase in the zinc content of the LM-4 alloy, it was necessary first to determine the effect of higher zinc contents on the properties of an alloy of this type. This paper summarises the investigation undertaken jointly by the Technical Committees of ALAR (Association of Light Alloy Refiners), and The Light Metal Founders Association, and also makes reference to work carried out by the British Non-Ferrous Metals Research Association with a similar series of alloys.

History

The original D.T.D.424 specification was published in 1940, and limited the maximum zinc content to 0·2% in both ingots and castings. Subsequently, owing to the difficulties of both the ingot producers and founders in maintaining these limits, the values were increased to 0·3% in ingots and 0·5% in castings, and these limits were adopted in LM-4 in B.S.1490—Aluminium and Aluminium Alloy Ingots and Castings—which made its appearance in 1949. The acceptance of the higher zinc content in castings was furthered by the results obtained by Glaisher[1] of the British Non-Ferrous Metals Research Association, and by Marshall.[2] Glaisher found no difference between the casting characteristics of D.T.D.424 containing 0·6% zinc and the zinc-free alloy, and in an unpublished report he showed that the tensile properties after 10 and 60 days were independent of the zinc content over the range examined, i.e., 0–0·6%. Marshall reported that in the production of many tons of castings in D.T.D.424 alloy, but containing 0·6% zinc, no effect on the mechanical properties or castability due to the zinc was detected.

In the U.S.A., too, the need to utilise all available raw materials to the greatest national advantage during the war years led Bonsack[3] to review the literature on the effect of minor elements, including zinc, on the properties of casting alloys generally. His findings, supplemented by tests which he carried out, suggested that American specifications were unrealistically restrictive in their limits for zinc, where this element was not a main alloying element, and that zinc did not influence the properties of casting alloys in the harmful way attributed to it by the early makers of specifications.

More recently, Colwell[4] has reported the results of a series of tests in which mechanical and physical properties were determined on the A.S.T.M. alloy CS43A (nominally 4% Cu, 3% Si), containing zinc up to 2%. In 1950 the B.6 Committee[5] of the A.S.T.M. published a report on tests its members had carried out on the mechanical properties of pressure die castings produced in the alloy SC84A (nominally 8% Cu, 4% Si) with 0·25–2% zinc. Neither the A.S.T.M. investigators nor Colwell found any lowering of tensile properties over this range of zinc. On the contrary, a small increase in elongation was found by the former in die castings and by the latter in sand and chill castings. Colwell also examined a number of physical properties and could find no difference in the thermal and electrical conductivities, the thermal expansion, or the freezing range of the low and high zinc compositions. The same author also reported results of strength and loss of weight tests on accelerated corrosion test specimens in the same alloy with zinc contents ranging from 1·5 to 6·5%. The results show that the severity of the corrosive attack and its effect on the mechanical properties of both sand and chill cast specimens is not dependent upon the zinc content.

From the properties of various cast alloys reported by Bonsack,[3] and more recently from tests made by Colwell and Trela[9] with the Al-Si-Cu alloy SC84A, it appears unlikely that zinc, up to at least 2%, would have any effect on the tensile strength and elongation of an alloy of the LM-4 composition at elevated temperatures. (This aspect has not been studied in the tests described in this report, but arrangements have subsequently been made to compare the creep resistance and hardness at elevated temperatures of LM-4 alloy containing 2% zinc with the zinc-free alloy).

There was, therefore, from the published literature, good reason to expect that an increase in zinc in the LM-4 alloy to 1·5 to 2% would have no detrimental effect on the mechanical properties, castability or corrosion resistance of the alloy, although it was not safe to assume with certainty from the American tests that

TABLE I.—COMPOSITION OF BASIC LM-4 ALLOY MELT.*

	Cu %	Mg %	Si %	Fe %	Mn %	Ni %	Zn %	Pb %	Sn %	Ti %	Al %
B.S.1490 LM-4	2·0–4·0	0·15	4·0–6·0	0·8	0·3–0·7	0·35	0·5	0·1	0·05	0·2	Remainder
Basic alloy	2·92	0·01	5·29	0·62	0·38	0·11	0·45	0·04	0·03	0·03	Remainder

* Single figures are maxima.

identical results for mechanical properties would be obtained with the British alloy. This uncertainty arose from the difference in the magnesium content between the American alloys tested (0·01–0·02%) and the maximum permitted by the LM-4 specifications (0·15%). It was known that the combination of magnesium and zinc in certain aluminium alloys had a pronounced age-hardening effect, and although it was expected that the magnesium-zinc compounds responsible would not appear in an alloy containing a large excess of silicon, it was in fact thought necessary to ascertain by practical tests whether the rate or extent of age-hardening of the LM-4 alloy was affected by the addition of zinc.

Experimental Programme

A simple programme of tests of mechanical properties on specimens aged at room temperature for varying periods was agreed by the Technical Committees of ALAR and the L.M.F.A. At the same time, an independent investigation into the effect of zinc upon the age-hardening and corrosion resistance of LM-4 was put in hand by the British Non-Ferrous Metals Research Association on lines agreed with ALAR. The findings of the B.N.F.M.R.A. have recently been published as an Association research report.[6]

Because of the known age-hardening effect of magnesium in this type of alloy, tests were made on three series of alloys containing 0·05, 0·1 and 0·15% magnesium with zinc contents of 0·5, 1·0, 1·5 and 3%. The lowest zinc content was selected in order that the behaviour of the alloys with the higher zinc contents would be compared with that of the standard LM-4 alloy which may contain up to 0·5% in castings. A single alloy containing 0·25% magnesium and 3% zinc, although of little practical interest, was included in the test as an extreme composition which would be helpful in establishing the age-hardening trend. Both sand cast and chill cast standard test bars (B.S.1490) were tested and the periods of age-hardening ranged from 24 hours to one year. In addition, a number of tests were made on specimens which had been stabilised or over-aged by heating for 4 hours at 250° C., since this is a condition in which LM-4 castings are occasionally used in practice. The programme was so arranged that each alloy in each combination of magnesium and zinc was tested by two of each of the eleven L.M.F.A. and the six ALAR members, who collaborated in the investigation, and in all, the properties of some 1,600 test bars were examined.

Chemical Composition.

All the alloys tested in the joint investigation (and in the B.N.F.M.R.A. programme) were prepared from one large melt of a basic alloy provided by one of the ALAR members. The composition was chosen as being typical of the LM-4 alloy in general use, with the exception of the zinc content which was designed to be the maximum (0·5%) permitted by the specification. The actual composition and the specification limits are given in Table I.

From this basic alloy each of the refiners produced, by the addition of magnesium and zinc, two of the agreed compositions, part of each of which was retained by the refiner and part supplied to two of the founders. Only magnesium and zinc were determined on each melt, but analyses were made at the beginning and end of each casting of ingots to detect any loss of either element during pouring. No loss, in fact, was found, but the contents given in Table II are the averages of the two or more figures obtained for each cast. Two sets of values are quoted where an alloy was made by two refiners. With the exception of the two melts A2 and A3, which contained 0·02% instead of 0·05% magnesium, the compositions achieved agreed sufficiently closely with those desired.

The zinc and magnesium contents shown in Table II are those of the ingots used for remelting for the production of test bars. In the tests made by the ALAR members, zinc and magnesium were redetermined on the test castings to ensure that no appreciable loss of either element had occurred. In no cases were the compositions of the test bars found to differ significantly from those given in Table II. The compositions of the test bars were not checked in the same way by the founders, but it is unlikely that they differed greatly from those of the ingots.

Melting and Casting.

Two quite different procedures were adopted by the ALAR and L.M.F.A. members. The former adhered closely to the controlled conditions described below in order to provide test results which would be strictly comparable. Each of the L.M.F.A. member-firms, on the other hand, followed their normal practice for routine inspection purposes. It was realised that this would result in a rather wide scatter in results and perhaps make correlation of properties with the zinc content more difficult, but it was thought that it would indicate the range of mechanical properties obtainable under ordinary foundry conditions.

In the ALAR series of tests, each member remelted approximately 60 lb. of ingots. Where it was found to be necessary, the melt was degassed using either dried nitrogen or hexachlorethane. D.T.D. sand cast bars were poured at temperatures between 690° and 700° C., with, as far as possible, a pouring time of between 10 and 15 seconds for each bar. Because of the possible effect of the cooling rate on the subsequent age-harden-

TABLE II.—MAGNESIUM AND ZINC CONTENTS OF ALLOYS PREPARED FOR THE EXPERIMENTAL PROGRAMME.

	A		B		C		D	
	Mg %	Zn %	Mg %	Zn %	Mg %	Zn %	Mg %	Zn %
1	0·04	0·55	0·11	0·44	0·16	0·49	0·25	2·89
2	0·02 0·07	0·93 1·0	0·10 0·10	1·04 1·02	0·16 0·16	1·0 0·96		
3	0·02 0·06	1·5 1·44	0·11 0·09	1·46 1·48	0·16 0·15	1·42 1·46		
4	0·04 0·06	2·93 2·85	0·09 0·10	3·03 2·85	0·14 0·15	2·85 2·95		

Fig. 1.—**Effect of zinc on the mechanical properties of sand cast bars containing: (a) 0·05%, (b) 0·1%, and (c) 0·15% Mg tested after 24 hours and 90 days.**

ing of the alloys, all test bars were allowed to remain in the moulds for 22 minutes, and were then allowed to lie on the foundry floor until cold. Chill cast bars were poured in standard wedge moulds pre-heated to, or adjusted to, a temperature of 100° C., and were removed from the moulds 3 minutes after casting and allowed to cool on the foundry floor. All bars were numbered to denote the order of casting.

Mechanical Tests.

Tensile test pieces, machined to the standard 0·564 in. diameter size, were tested under the conditions described below. Each composition was tested by four laboratories (two founders and two refiners), employing in each case between three and six test bars. In the ALAR tests, the order of selection of test bars was made in such a way that any variables associated with the order of casting would, as far as possible, balance out. Tensile strength, elongation (by the hairline method), and Brinell hardness were determined on each specimen. In addition, proof stress determinations, generally one for each condition, were carried out by the refiners.

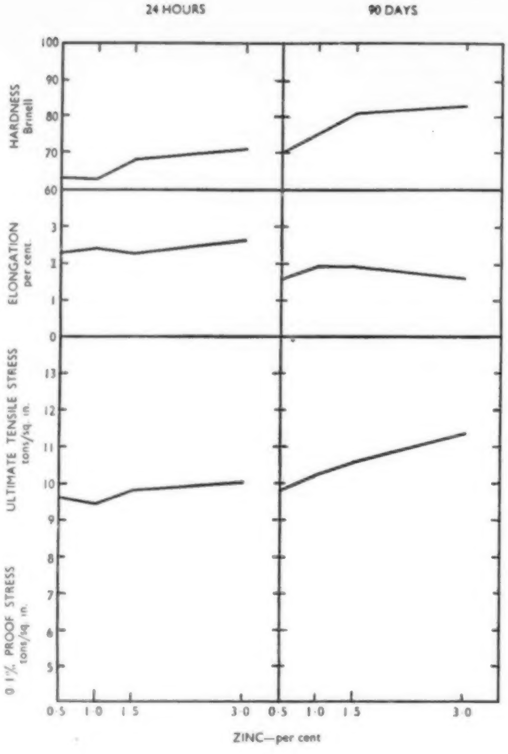
Condition.

Mechanical tests were made on specimens stored at room temperature for the following periods from the time of casting: 24 ± 2 hours; 7 days; 30 days; 90 days; 365 days. Furthermore, a stabilisation treatment consisting of a 4-hour soaking at 250° C. followed by cooling in air was applied to a number of bars of each alloy. Generally the interval between casting and this treatment was 7–10 days, the bars being tested 1–2 days later. Some of the bars so treated were stored for a further 90 days at room temperature, in order to ascertain whether the stabilisation was complete.

Discussion of Results

No attempt is made in this paper to reproduce the vast number of results obtained from the ALAR/L.M.F.A. tests, but most of the data has been presented in the form of graphs. At the same time, in the absence of the individual results, it is necessary to comment on the order of scatter. Generally, the agreement between the triplicate, or larger number of results from single laboratories, is very close, but the scatter between the different laboratories is of a larger order. The results show a tendency for most laboratories to be *consistently* higher or lower than others throughout for all the results in a particular series. This is most noticeable with the founders' results, where no attempt was made to standardise conditions, and suggests that the differences are related to the technique of melting and casting the test bars. As the main purpose of the investigation was to examine the effect of zinc on a comparative basis, and not to determine absolute properties, this tendency for results to be at a different level for different laboratories may justifiably be discounted by averaging the sets of results for each alloy and condition.

It is, nevertheless, of practical interest to note that appropriate foundry technique has enabled some of the investigators to obtain mechanical properties considerably in excess of those shown in the illustrations.

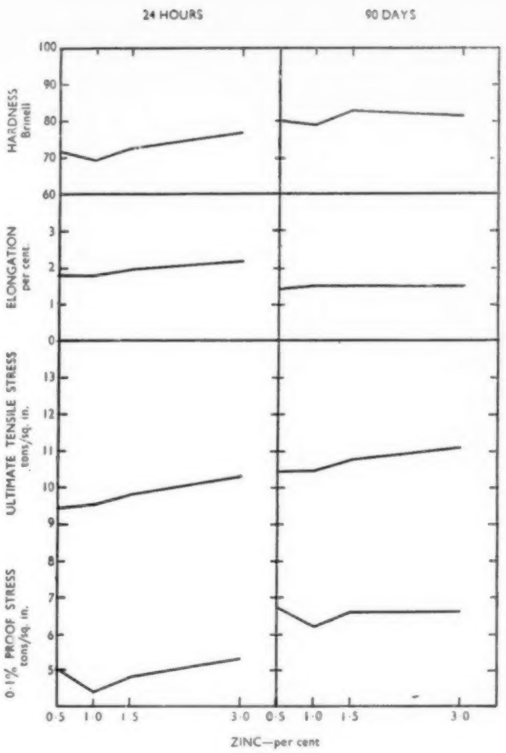


(a)

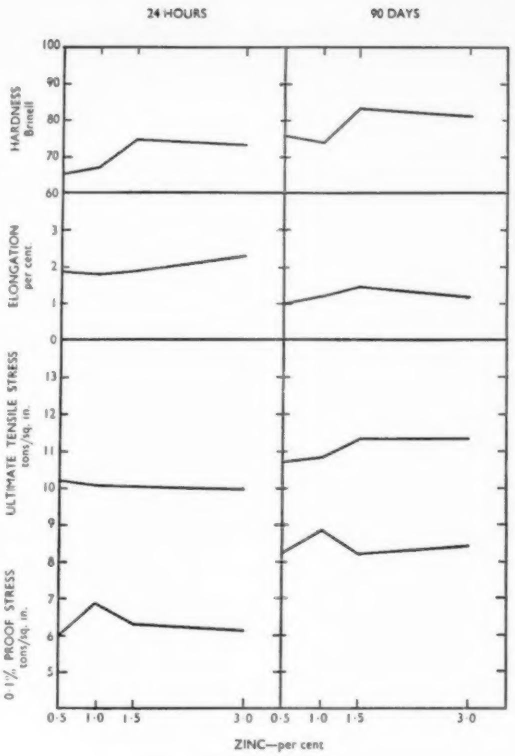
Furthermore, the first tests were made 24 hours after casting, and it is know that some ageing takes place during this time, at least in the alloys containing magnesium.[8] Consequently, if in practice tensile tests were made with a smaller time lag after casting, slightly higher elongation and slightly lower tensile strength values would be obtained.

All the results for sand cast specimens submitted for the 24-hour and 90-day ageing periods for each of the three magnesium contents have been assembled graphically in Fig. 1. Each point on the curve is the average of results from four laboratories and in most cases of 18 individual values. (The proof stress curves are not strictly comparable with the others as results were only submitted by the ALAR members). Fig. 1 has been drawn by simply joining the plotted average properties against the zinc contents examined, and no attempt has been made to draw a continuous or " best " curve through the points. The method used, whilst perhaps the only justifiable one, has the disadvantage that it tends to emphasise the peaks and inflexions which are of lesser importance than the general trend of the curve and, as explained earlier, are due to foundry technique and not to a difference of zinc content.

Fig. 1 shows quite clearly that whether the specimens are tested soon after casting or after ageing for three months, an increase in the zinc content from 0·5 to 3% has no harmful effect on the mechanical properties, and that this is true irrespective of the magnesium content within the limits of the LM-4 standard. The curves do, in fact, illustrate a small increase in tensile properties and hardness with increasing zinc.



(b)



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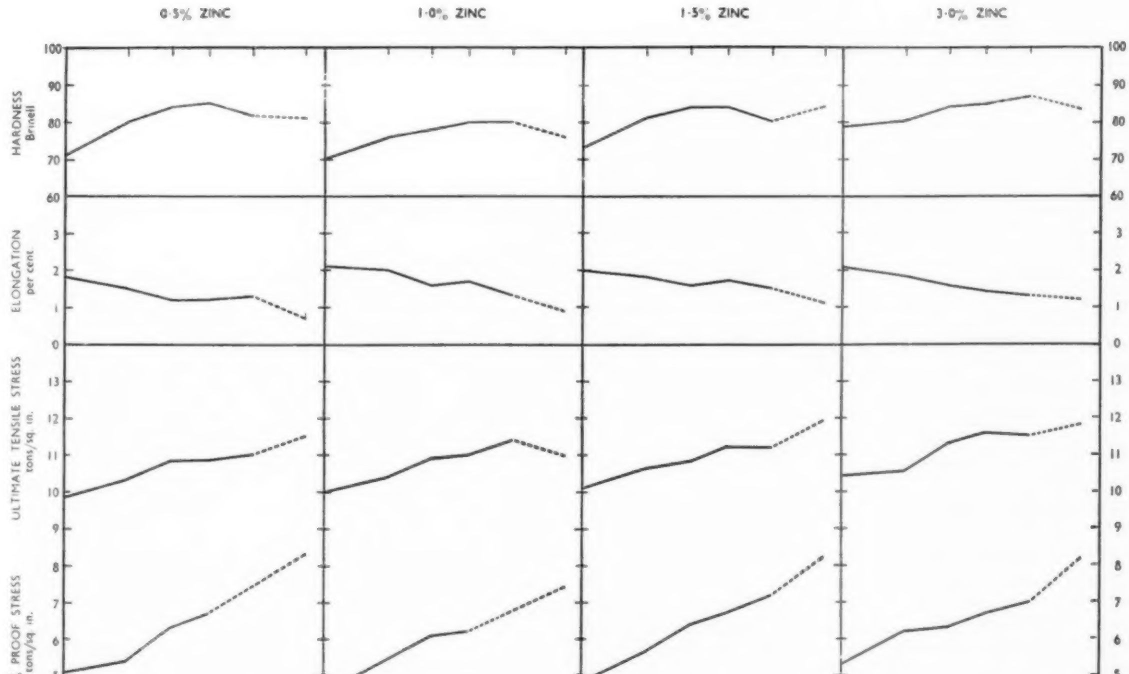

Fig. 2.—Effect of room temperature ageing on sand cast bars containing 0·1% Mg.

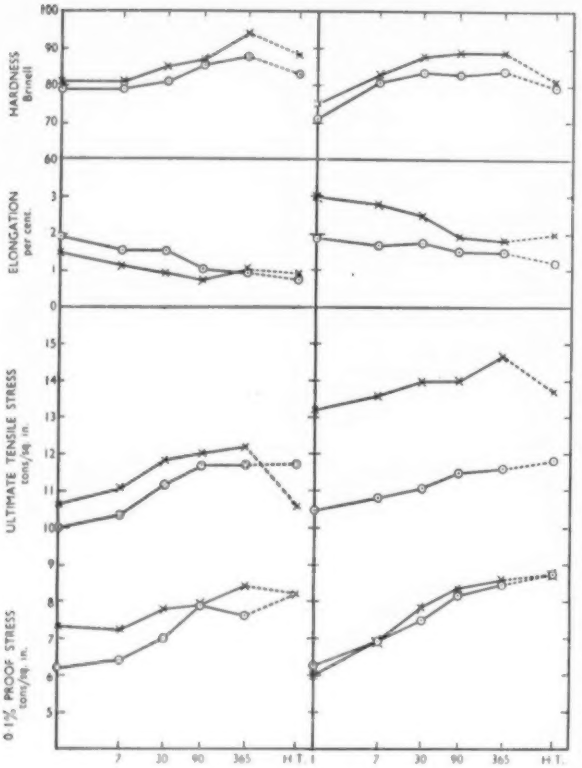

Fig. 3 **Fig. 4**

Fig. 3.—Age-hardening of sand cast bars containing 3% Zn and 0·15% Mg (circles) and 0·25% Mg (crosses).

Fig. 4.—Age-hardening of sand cast (circles) and chill cast (crosses) bars containing 1·5% Zn and 0·15% Mg.

Results for chill cast test bars have not been plotted in Fig. 1 as they were submitted by fewer laboratories, and the curves would not therefore be strictly comparable. Curves based on the averaged results of those laboratories who returned results for both sand and chill cast specimens were found to be mainly parallel, the chill cast curve showing rather higher properties than the curve for sand cast bars. They confirm that the effect of zinc in chill castings is similar in trend to that in sand castings. Reference is made later to chill castings in connection with age-hardening (Fig. 4).

There is ample evidence from Fig. 1 that considerable age-hardening occurs within three months of casting, but this is better illustrated in Fig. 2. The influence of magnesium can also be seen in Fig. 1, but this is already well known[7, 8] and apart from repeating that its effect is independent of the zinc content, and noting that considerable age-hardening occurs with as little as 0·05% magnesium, no further comment is necessary.

Curves showing the changes in mechanical properties due to age-hardening were drawn for each of the three magnesium contents. They are essentially similar in form and only those for the alloys containing 0·1% magnesium have been reproduced in Fig. 2. The curves, each of which is based on the results from two laboratories, show the properties for sand cast specimens stored at room temperature from one day to a year. The last points are joined by dotted lines with the points corresponding to the properties obtained after heating the test bars for four hours at 250° C., although these are not related to the time scale. The dotted lines are not intended to indicate the course of ageing after one year, but have been added simply to assist comparison.

The rate of age-hardening, as shown by the slope of the curves, clearly remains unaltered with changing zinc content, and the difference in tensile properties, including elongation, between the bars tested after one day and after one year is no greater for the alloys containing 3% zinc than for those containing 0·5%. The properties of the specimens after stabilising treatment are generally close to those of specimens aged for one year, with the exception that the 0·1% proof stress values are appreciably higher for the stabilised bars. No further change was detected in the properties of the test bars which were stored for 90 days after the stabilising treatment.

The results from the series of sand cast specimens containing 0·25% magnesium and 3% zinc, which were referred to earlier, have been plotted in Fig. 3, together with the curve for the 0·15% Mg, 3% Zn alloy for comparison. The two curves are roughly parallel to one another, indicating that although the strength and hardness are increased and the elongation reduced by the additional 0·1% magnesium, the rate of ageing is approximately the same. There appears, however, to be a tendency for the elongation curves to coincide after the maximum period.

The results for chill castings have not been reproduced in the previous figures, but it has been stated that the curves follow the trends of those illustrating the properties of sand castings. Fig. 4 is included as an example of the relationship between sand and chill castings. The alloy contains 0·15% magnesium and 1·5% zinc, and the properties are plotted in an ageing curve similar to Figs. 2 and 3, with those of sand castings of the same composition. The pattern of age-hardening of the chill castings follows closely that of the sand castings, although the properties are higher.

Conclusions

Comparison of the properties of the LM-4 alloy with additions of zinc up to 3% has shown that the tensile properties and hardness of the alloy at ordinary temperatures are not affected by variation of zinc within this range. The investigation has also demonstrated that the age-hardening characteristics do not alter with increasing zinc between 0·5 and 3%.

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Birmingham Engineering Centre

THE Birmingham Exchange and Engineering Centre has recently circulated the first of a series of monthly News Letters designed to give exhibitors and other interested organisations an insight into the various activities of the Centre, and to encourage all interested in engineering to make use of the Centre's extensive facilities. Further particulars concerning the Centre and its News Letter can be obtained from the former at Stephenson Place, Birmingham, 2 (Tel.: Midland 1914).

Modern Temper Mill Drive

G.E.C. Installation at Whitehead Iron and Steel Company

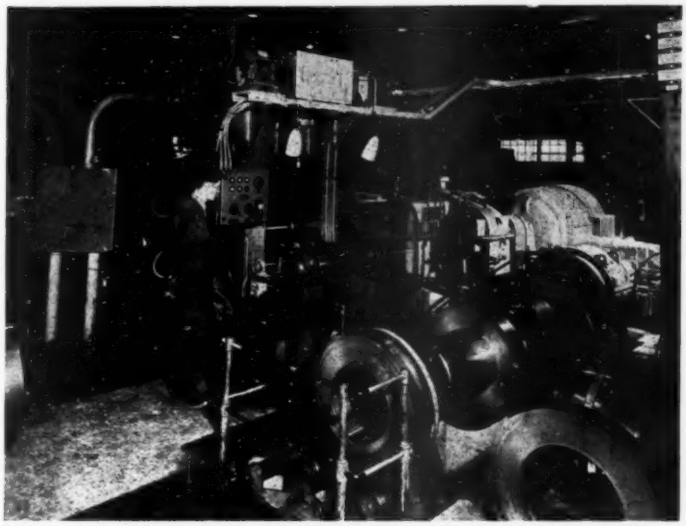

Fig. 1.—View from the entry side of the mill, showing the 200 h.p. mill motor and 50 kW. drag generator.

AFTER cold reduction to finished gauge, coils of steel strip are usually subjected to a stage of skin passing to impart to the steel the desired mechanical properties and surface finish. The skin passing is carried out in a temper mill in which the strip is subjected to a combination of high pressure and longitudinal tension as it passes through the rolls, and the various physical properties and degrees of temper and surface finish which can be imparted are controlled by the tension and pressure which are applied to the strip.

To ensure uniformity in the finished product, the selected tension must be maintained throughout the temper rolling process, including the periods of acceleration and deceleration of the mill, and must not be affected by the changing diameters of the coils as the strip is unwound and reeled. The essential features of a satisfactory control scheme for a temper mill are therefore high speed of response together with adequate sensitivity and stability.

At the Courtybella Works of the Whitehead Iron and Steel Co., Ltd., Newport, where a new 21-in. single-stand 4-high temper mill has recently been commissioned, these requirements have been met by adopting a control scheme comprising a Ward-Leonard system operating in conjunction with control exciters. The temper mill was supplied by the Davy & United Engineering Co. Ltd., and the whole of the electrical plant and control gear by The General Electric Co. Ltd.

A general view of the mill from the entry side is shown in Fig. 1. The uncoiler in the foreground is coupled through gearing to a drag generator rated at 50 kW., 0/350/350 volts, 0/300/950 r.p.m., and the mill rolls are driven through reduction gears by a D.C. motor rated at 0/200/200 h.p., 0/250 volts, 0/300/750 r.p.m. On the delivery side of the mill, Fig. 2, the coiler shown on the left is driven through reduction gearing by an 0/150/150 h.p., 0/350/350-volt, 0/300/750-r.p.m. D.C. motor which is equipped with an electro-magnetic brake. The motors are fitted with pedestal journal bearings arranged for oil-ring lubrication, and the drag generator with end-shield ball and roller bearings. All three machines are forced-ventilated with cooling air supplied by a 27-in. diameter fan driven by a 5 h.p. motor.

Fig. 2.—The delivery side of the mill, showing the main control cabinet and the 150 h.p. coiler motor.

The direct current supply for the mill drives is obtained from a motor generator set (Fig. 3,) installed in a substation adjacent to the mill. The set comprises a 435-h.p. 6-kV. slip-ring induction motor running at 970 r.p.m., direct-coupled to a D.C. generator with an output of 0/300 kW. at 0/250 volt. A totally enclosed liquid starter is provided for the motor.

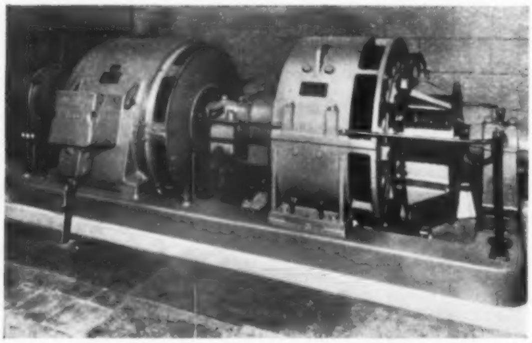

Fig. 3.—The 435 h.p., 970 r.p.m. motor-generator set in the substation.

For the control of the mill drives, three smaller motor-generator sets are provided; these are illustrated in Fig. 4. The first consists of a 70-h.p. 1,450-r.p.m. squirrel cage motor driving a 37-kW. delivery reel booster, a 20-kW. entry reel booster and a 9·5-kW. constant-voltage exciter; and the remaining two sets are groups of four control exciters driven at 2,900 r.p.m. by 6-h.p. motors. The three sets are mounted in the substation adjacent to the low voltage switchboard, Fig. 5. Control cabinets are fitted to the entry and delivery sides of the mill and both cabinets are equipped with drive selector switches, " inch " controllers, emergency stop buttons and indicator lamps. In addition, the delivery cabinet is fitted with a 5-position " run " controller as well as selector and controller switches for the mill screwdown drives.

The Control Scheme

The G.E.C. control exciter which forms the basis of the control scheme for the mill is fundamentally a standard D.C. generator with conventional armature windings and brushgear. It differs from the standard machine in that its magnetic circuit is completely laminated, and that a number of separate field windings is provided for the various control and stability circuits. In this application the control exciters, in addition to meeting the essential requirements already outlined, provide a control scheme which enables coils of a wide range of widths and thicknesses to be processed.

A simplified schematic diagram of the control scheme is shown in Fig. 6. It will be seen that the drag generator $G4$ and reel motor $M2$, and their respective boosters $G2$ and $G3$, are each excited by means of two control exciters connected in cascade. The power supply for $G4$, $M2$, and the main mill motor $M1$ is obtained from generator $G1$ of the main MG set. The various control sequences are initiated by adjusting the voltages applied to the field windings of the motors, generators and exciters, the field supplies being obtained from the constant voltage exciter CVE. Overall speed control of the mill during acceleration is achieved first by increasing the field and consequently the output voltage of the main generator $G1$, and subsequently by weakening the field of the mill motor $M1$. The reverse procedure is followed during deceleration, while to stop the mill three forms of braking are provided. In normal use a regenerative scheme is used in conjunction with friction braking, while for emergency stops dynamic braking is employed.

To keep the tension in the strip constant as it is " paid off " the entry reel and " built up " on the delivery reel, it is necessary, for any given constant speed of strip or speed of $M1$, to keep the outputs of both $M2$ and $G4$. constant. This means that both the current flowing and the voltage generated in each reel motor armature must be kept constant. In addition, when the strip speed varies during acceleration and deceleration, the voltage generated in each armature must vary in direct proportion to the strip speed. Control exciters $PE2$ and $ME2$ keep the voltage generated in the armature of $G4$ constant irrespective of its speed for a given strip speed, and proportional to the strip speed when this varies. Control exciters $PE4$ and $ME4$ perform the same function for $M2$. The exciters $PE1$, $ME1$, control the field of boosters $G2$ to keep the current in $G4$ constant, and exciters $PE3$, $ME3$ control the field of $G3$ to keep the current in $M2$ constant.

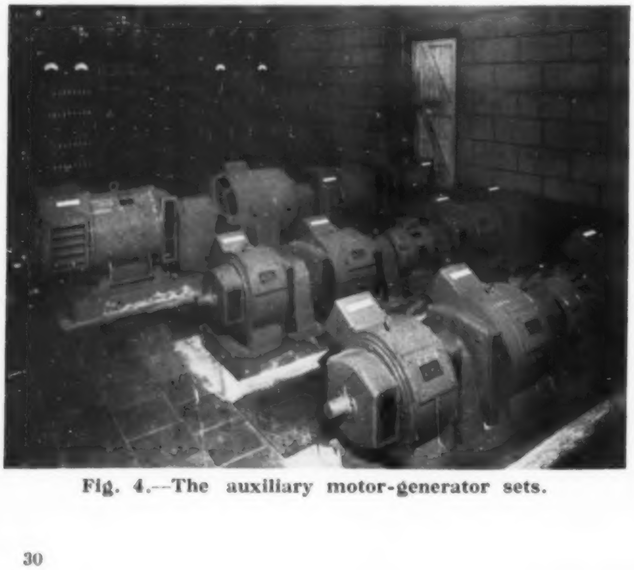

Fig. 4.—The auxiliary motor-generator sets.

Fig. 5.—The low-voltage switchboard.

Delivery End Control

The tension reference winding $A3$ on pilot exciter $PE3$ is energised from the constant voltage busbars through the delivery reel tension setter $R9$, which is mounted on the delivery control cabinet. This winding builds up the excitation and output of booster $G3$ until winding $A3$ is almost balanced by winding $D3$, which is energised from the compoles of motor $M2$ and therefore produces an effect proportional to the motor current. Thus this current and hence the strip tension is controlled by the strength of field $A3$.

The speed of reel motor $M2$ is dictated by the strip speed or the speed of mill motor $M1$, and by the diameter of the coil on the reel. The reel motor must slow down with respect to $M1$ as the strip builds up on the reel, and in order to maintain the e.m.f. of the reel motor constant for a given strip speed or speed of $M1$, the motor field is progressively strengthened by the associated control exciter set $PE4$—$ME4$.

This is accomplished in the following manner. The reel motor $M2$ is provided with two field windings, $Y4$ and $X4$; $Y4$ is sufficient to give the correct generated voltage in the reel motor armature when the motor is running at its maximum, or empty reel, speed, and winding $X4$ assists $Y4$ to keep the generated voltage constant for a given constant strip speed as the speed of the reel motor decreases with coil build-up. Winding $X4$ is connected in series with a rectifier, so that under no circumstances can it oppose $Y4$ and cause overspeeding of the reel motor.

Field winding $X4$ is controlled by control exciters $ME4$ and $PE4$. Winding $A4$ of $PE4$ is energised by the difference of two e.m.f.s: one is supplied by tacho-generator TG driven by mill notor $M1$, and is proportional to the desired strip speed, while the opposing e.m.f. is that generated in the reel motor armature. If the reel motor e.m.f. tends to be less than that of the tacho-generator, as when the motor slows down under coil build-up, the resultant voltage across $A4$ increases and causes exciters $PE4$ and $ME4$ to strengthen field winding $X4$ of the reel motor and restore its e.m.f. to the correct value to oppose the e.m.f. of the tacho-generator. Field winding $D4$ on exciter $PE4$ is energised from the compole winding of the reel motor, and compensates for the resistance drop in the armature winding of the reel motor.

Acceleration Compensating Motor

During acceleration the delivery reel motor $M2$ requires increased current to provide the accelerating torque, as the strip tension would otherwise be reduced. Similarly, during deceleration, the stored energy of the reel and motor must be given up, and an increased strip tension would result if the current were kept constant. Thus it is necessary to provide excitation which increases the tension reference field $A3$ during acceleration, and decreases it during deceleration. For this purpose winding $E3$ is connected in series with an acceleration compensating motor ACM and a small series booster SB. Fig. 7, across the armature and compoles of delivery reel motor $M2$. Under steady conditions motor ACM produces a back e.m.f. to balance the voltage across reel motor $M2$, and takes only a small current to supply its rotational losses. The effect of this loss current on winding $E3$ is neutralised by a slight preset adjustment of the tension reference field $A3$.

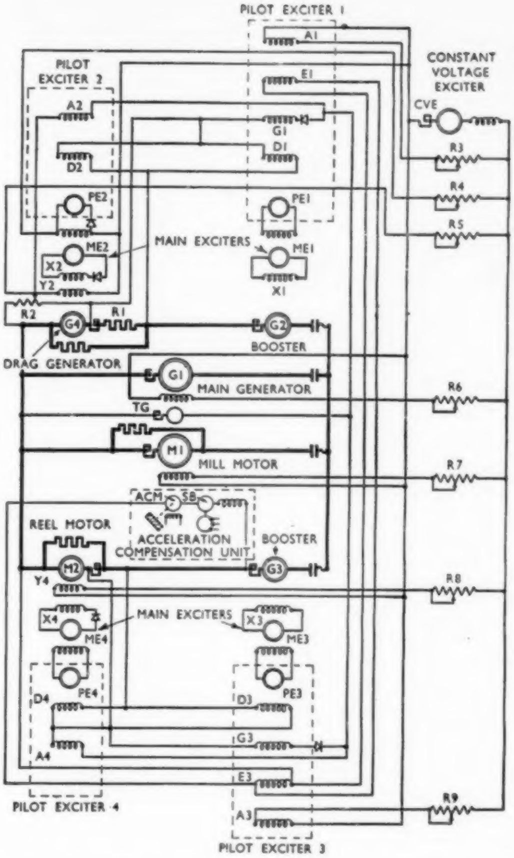

Fig. 6.—Simplified schematic diagram of the control exciter scheme.

The acceleration of motor ACM will be the same as that of the reel motor, since they are both proportional to the rate of change of voltage across the reel motor armature. The current taken by motor ACM is proportional to the inertia of the flywheel and to its acceleration, and thus the current taken by ACM during acceleration is a measure of the acceleration of the reel motor armature. This current is used to energise winding $E3$ so as to assist winding $A3$ thus automatically increasing the current setting by the amount required to accelerate the reel motor armature.

During deceleration the back e.m.f. of motor ACM exceeds the voltage of the reel motor $M2$, and the current through ACM is reduced and eventually reverses, causing the flywheel to drive motor ACM as a generator. Winding $E3$ then acts in the reverse sense to oppose winding $A3$, thus automatically reducing the current setting by the amount required to decelerate the reel motor armature. The series booster SB compensates for the IR drop in the circuit, and ensures that the back e.m.f. of motor ACM accurately reflects the voltage generated by the reel motor $M2$ at all times. The current in motor ACM and hence in field $E3$, thus reflects the rate of change of speed of motor $M2$, and provides accurate compensation under changing speed conditions.

In the event of strip breakage, the booster control attempts to maintain constant current in reel motor $M2$,

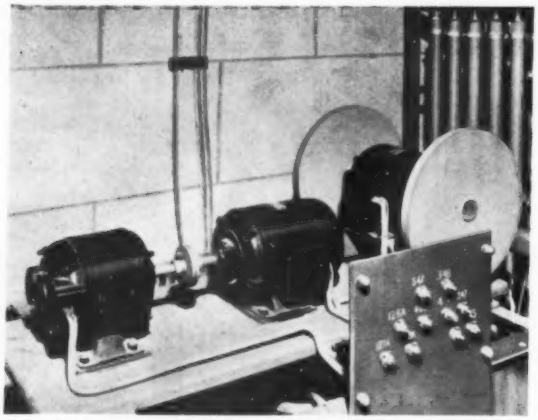

Fig. 7.—The acceleration compensating motor, with series booster and driving motor.

and since this current is no longer providing tension, it tends to accelerate the reel to an excessive speed. To limit this, winding *G*3 is arranged to oppose the tension setting field *A*3 when the e.m.f. of the reel motor appreciably exceeds the voltage of the tacho-generator, thus limiting the current which the booster will produce in the armature of the reel motor, and preventing any dangerous rise in speed. To prevent winding *G*3 from carrying current when the e.m.f. of the reel motor is less than that of the tacho-generator, it is connected in series with a metal rectifier.

Apart from the field windings already described there are additional windings on the pilot exciters to correct any tendency to instability due to the sensitivity and rapid repsonse of the exciters to sudden changes.

A stalled tension switch is provided which enables a pre-selected value of tension to be maintained in the strip when the mill is stopped. This switch transfers the connections of the tension reference fields *A*1 and *A*3 of exciters *PE*1 and *PE*3 from the running tension setters *R*3 and *R*9 to other setters which are adjusted to give the desired value of stalled tension. The field of exciters *ME*2 and *ME*4 are simultaneously connected to the constant voltage busbars via further stalled tension setters. The design of the control scheme insures that stalled tension must be applied to the strip before rolling can be commenced.

Entry Tension Control

The tension is controlled at the entry end, in a similar manner to that described for the delivery end, by controlling both the current developed by the drag generator *G*4 and its generated voltage. Both these quantities are kept constant for a given strip tension and strip speed, and the generated voltage is kept proportional to the strip speed when that varies. Control exciters *PE*2, *ME*2 control the generated voltage of *G*4 and control exciters *PE*1, *ME*1 control the current by varying the field of booster *G*2.

The main difference in the control is that whereas on the delivery side the field winding of *ME*4 is fed direct from the armature of *PE*4, on the entry side it is supplied from the constant voltage exciter via resistance *R*4, and this acting alone gives its maximum or full reel value. As the coil diminishes in diameter for a given strip speed, the speed, and consequently the e.m.f., of *G*4 tends to increase above that supplied by tacho-generator *TG*. The voltage excess is applied to the field winding *A*2 and causes the e.m.f. of *PE*2 to diminish and progressively divert current from the field winding of *ME*2, thus lowering and correcting the e.m.f. generated by *G*4, A metal rectifier in series with *PE*2 prevents over-excitation of the field winding of *ME*2. A metal rectifier is also connected in series with winding *X*2 and prevents the excitation from becoming reversed and causing an excessive current to flow in the armature of the drag generator. A further winding *D*2 on exciter *PE*2 is connected across resistor *R*1 and the compoles of drag generator *G*4. This winding carries a current which is proportional to the drag generator current, and provides compensation for the IR drop in the armature.

During acceleration, the drag generator must produce less current for a given strip tension, and similarly during deceleration an increased current is necessary to produce the deceleration torque. Consequently it is necessary to provide an excitation which opposes field *A*1 during acceleration and assists it during deceleration, and for this purpose winding *E*1 is connected in parallel with winding *E*3, but in the opposite sense. Compensation for change of speed is thus accomplished in the manner already described for the delivery end of the mill.

In the event of strip breakage, the booster control attempts to maintain constant current in the drag generator, but this current is no longer produced by the torque resulting from the tension in the strip. The drag generator thus slows down, and would eventually tend to run in the opposite direction, but is prevented from doing so by winding *G*1, which operates when the e.m.f. of the drag generator falls appreciably below the voltage of the tacho-generator *TG*. Winding *G*1 thus opposes the tension setting field *A*1, and limits the current which the booster produces in the drag generator armature to a safe value. A rectifier is included in the circuit to prevent winding *G*1 from carrying current in normal operation, when the e.m.f. of the drag generator exceeds that of the tacho-generator.

Acknowledgment is due to the Whitehead Iron and Steel Co. Ltd., for permission to publish this illustrated description.

Additional British Melting Equipment for India

FURTHER to their recent order for four arc melting furnaces, value £115,000, The Tata Locomotive and Engineering Co., Ltd., of India, have commissioned a mains-frequency coreless induction melting, super-heating and holding furnace from the same supplier, Birlec, Ltd., of Birmingham, England. This 5-ton capacity unit will be installed in the same foundry as the four arc furnaces, thus completing the most modern steel and iron foundry, certainly in the East, and possibly in the whole world.

The induction furnace will have a melting rate of 8 cwt. per hour, or a super-heating rate of 100° C. per 6 tons per hour, whilst automatic power reduction equipment will be incorporated for strictly holding duties. Flexibility of foundry operation will be the most important advantage obtained from these five furnaces. They will be able to produce : (*a*) steel castings of 20 tons and over ; (*b*) small steel castings in a fully mechanised foundry ; (*c*) grey iron or alloy iron castings in a fully mechanised foundry. Moreover, the induction furnace can also be used for the production of alloy irons and for the economical reclamation of cast iron borings.

Progress in Powder Metallurgy

By H. W. Greenwood*

In reviewing progress in the field of powder metallurgy the author makes reference to a number of important developments. Titanium, from being a "rare" metal, is now being produced in commercial quantities, whilst what may be described as "powder extraction metallurgy" is likely to play an important part in dealing with low grade ores. The impregnation of porous metal bodies is a technique of increasing importance applicable to both metallic and non-metallic infiltrants.

TWO years ago[1] we reflected that the first symposium on powder metallurgy to be held in this country had taken place five years earlier[2]. That is now seven years ago and last month we had the Symposium on Powder Metallurgy, 1954, which was organised by the Iron and Steel Institute in association with the Institute of Metals.

From the point of view of the progress of powder metallurgy it is most interesting to compare the programmes of the two symposia. At that of 1947 some 28 papers were communicated, all from British sources and, with two exceptions, all dealing with British materials and processes. In contrast to this we have just had, at the 1954 symposium, a series of 51 papers, of which 11 came from foreign countries. Another notable difference has been the much wider ambit of the papers and the evidence of the desire among powder metallurgists to study the theoretical aspects of their subject, and to base some, at least, of their research work on examining the possibilities of recent theoretical findings. A notable example of this has been the comparatively recent success in applying deductions from the domain theory that it should be possible to prepare permanent magnets from material formerly considered quite unsuitable[3]; also the success in producing material easily magnetisable in one direction.

Titanium Developments

Another difference between activities seven years ago and those of to-day is the great interest now taken in (*a*) what used to be looked upon as rare metals, such as titanium, zirconium, tantalum; (*b*) a wide range of carbides and the growth in their general application; and (*c*) the powder metallurgy of high melting point materials, for which there was a whole section comprising some 12 papers last month, but virtually no mention at the earlier symposium. A very striking commentary on the speed of development in the use of titanium and allied metals are the figures provided by American technical periodicals concerning plans for their production in the United States. Somehow we do not find it strange to read an announcement that the production of titanium sponge for the next five years to meet U.S. Government contracts alone will be over 30,000 tons per year. That such high production figures should be called for is not surprising if we remember that a new light-weight titanium alloy is being used for the production of weapons, and the construction of tanks and similar vehicles, and that this new alloy is considered suitable for replacing steel as it is 40% lighter, bulk for bulk, has a tensile strength of some 192,000 lb./sq. in., which is about 40,000 lb./sq. in. higher than that of any other commercial alloy of titanium now being produced. There are in addition many other fields in which titanium can offer outstanding advantages.

One of the most accessible and informative sources of information on titanium is the 24th Autumn Lecture to the Institute of Metals by Dr. Maurice Cook[4]. In that lecture, speaking of the manifold uses for which titanium was particularly suited, he said: "Nor is it necessary to speculate on other uses (i.e., other than the aircraft industry) for it seems sure enough that the consumption of the metal in much greater quantities for other applications—and already there are many for which titanium and its alloys are well suited—will quickly follow when it is more readily and more cheaply available."

One of the outstanding characteristics of titanium is its resistance to corrosion; this added to its light weight, provides an attractive combination, which has a particular appeal for the marine engineer, but up to the present it has not found much application in this field owing to high price and the fact that it has not been available in quantity.

Materials having somewhat similar resistance to corrosion include the stainless steels, metallic carbides and kindred materials, and there has been much progress in their application, particularly in chemical engineering. This is reflected in the papers presented in Group 3 at the recent symposium, embracing the manufacture and properties of structural engineering components, including studies of porous stainless steel and the porosity and air permeability of sintered iron and iron-copper. Materials having outstanding resistance to corrosion and also to oxidation and similar attack are found among the ceramic bodies and also the ceramals—materials falling between the true ceramics and metals. The cermets and ceramals, consisting largely of metal powders and their oxides, have attracted much attention and have been the subject of many investigations with a view to their application to the electronic industry.

Many of these special materials are not necessarily new, but they do possess greatly enhanced properties when compared with their predecessors. They provide at least a partial answer to the question as to what is powder metallurgy's aim. They underline the demands from industry for materials having high strength, high resistance to corrosion, high melting points, good fatigue resistance and high modulus and creep strength, with the lightest weight possible. A catalogue of perfection if you will, but a goal that the metallurgist is working towards, and it is also true that the metallurgist and the powder metallurgist are both producing metals and alloys which in performance and properties are much superior to anything available previously.

Impregnation Techniques

The mention of ceramics and ceramals is a reminder of some of the valuable products that have come from the

* Powder Metallurgy, Ltd., London.

impregnating of porous metal bodies, not only with other metals or alloys, but with some of the newer chemically and physically inert materials such as Fluon, Polythene and related bodies. It is only necessary to remember the almost zero coefficient of friction possessed by Fluon to realize the possibility inherent in possessing such a material, and making use of it in providing bearings, gears and similar mechanisms. Not only is friction reduced to a minimum, but other most desirable qualities are possible. The value of impregnating with inert plastics brings to mind the use of impregnating techniques in simplifying and facilitating the machining and working of alloys having a high tungsten content which offer considerable difficulty in working. Copper has been used as impregnating metal[5], and tungsten parts having some 83% of their full density can be machined, milled, drilled or turned as required. Once the necessary form is attained the copper is evaporated off by holding the parts at 1,550° C. for 15 minutes in a vacuum of the order of 10^{-5} mm. mercury. The process has particular advantage where the tungsten parts provide cathodes in electrical discharge tubes, as the evaporating of the copper ensures that the pores of the tungsten compact are not closed.

There is evidence of the more widespread recognition that by the use of impregnating techniques greater and more exact control of the properties of parts made by powder metallurgy are possible. Attention in the United States[6] has been drawn to the advantages and remarkable flexibility obtainable in the production of cams infiltrated with brass. The part was impossible to make with sufficient accuracy by any machining method, but brass-infiltrated parts not only gave the necessary accuracy, but the brass-infiltration increased resistance to abrasion and wear. There has also appeared a review of the theory, practice and economics of infiltrating iron skeletons with copper-base infiltrants[7].

Increased Metal Powder Consumption

On a general survey of powder metallurgy as practised to-day there is good evidence of important development and progress over a very wide front. Not only can a marked increase in the use of powder metallurgical techniques be found, but there is a notable difference in the type and quality of the publications on the subject to-day compared with those appearing several years ago. With this progress, as might be expected, there has been a considerable increase in the consumption of metal powders. Iron is the outstanding example of this, and it is of interest to note that the increased consumption is not confined to any one country, but is spread over all the industrial nations of the world, with the U.S.A. leading. Some eight years ago there were about ten firms producing about a million parts daily. To-day the U.S.A. has some 60 firms producing 5 million parts per day, many of them of much larger size than the parts produced years ago. Parallel with the increase in numbers there has naturally been increase in the powder tonnage used, the consumption during the last eight years having risen from 8,000 tons to 40,000 tons per year and the figure is still rising. Several European countries have registered notable progress in the last few years. This has been particularly true of France, Germany, Italy and Sweden. In every case the largest part of the various increases has been in iron powder, with copper and copper alloys in the second place.

Powder Extraction Metallurgy

While the figures quoted are very small in comparison with the quantities of metals used in general all over the world, there are certain connections between general metallurgy and its problems and the part powder metallurgy can play, and is playing, that are of the greatest importance in any assessment of the services and importance of powder metallurgy. One of the preoccupations of the metallurgist, indeed of every large user of metals to-day, is the speed with which the large and rich deposits of the commoner metals are being used up, and the answer to the question as to what action can be taken to deal with this state of affairs. One line of action is quite plainly revealed : we have to learn how to obtain supplies of metals by working low grade ores, and the outstanding possibilities in this direction are the use of leaching by chemical reagents, and, where the ores are of suitable type, the concentration of metal values by flotation or allied methods.

The product of many of the leaching methods—in which after solution by appropriate reagents the metals are precipitated by reducing agents, collected by ion-exchange batteries, or separated as powder electrolytically—are, or can be, metal powders, and in quite a number of cases the powders are of rather better purity than many commercial qualities of metal to-day. That means the elimination, if possible, of the rather expensive methods of dealing with powders, unless powder metallurgy is the method of utilisation. Fortunately, there has appeared, largely during the last four or five years, a method of utilising large quantities of metal powder by rolling it into metal strip. This has been achieved on a semi-commercial scale, as a continuous process, while experimental work has also been carried out on the production of metal sheet from powder by a process of flame spraying. Already there is quite an amount of literature on the subject, one of the best general accounts with a certain amount of the history of the process being that given by Dr. H. Franssen[8]. There is at present in progress in the Department of Metallurgy at Cambridge University research work on the continuous compacting of powdered metals, which was described in May of last year[9].

A month earlier, on April 28th, 1954, Dr. W. D. Jones presented to the 10th Annual Meeting of the Metal Powder Association of the U.S.A. at Chicago a paper on the manufacture of sheet metal from metal powder[10], in which he described the simultaneous, but independent, development of two branches of metallurgy : first, the continuous fabrication from powder by rolling, extrusion and spraying ; and second, the preparation of powder from ores and concentrates. For the latter branch Dr. Jones proposes the designation "powder extraction metallurgy" and defines it as comprising processes of extraction of metals from their ores or concentrates in which the primary end product is a metal powder. It is pointed out that a number of metals are capable of being produced as powders, and in some cases are actually being produced as such. The results of attempts to apply continuous fabrication methods has encouraged the search for more economical and more efficient methods of fabricating metal powders. Dr. Jones discusses powder production methods and their possible application to the two basic metals of industry, copper and iron. The possibility of utilising flame spraying for the production of sheet is discussed, and it is pointed out

that already claims have been made, based upon experimental work, that alloying occurs by diffusion in powder rolling of alloys such as cupro-nickel, bronze, stainless steel and certain of the aluminium alloys. There are many cases where the inter-diffusion by rolling presents no difficulties, but in others, particularly heat resistant alloys calling for high temperature, the use of the powder flame spray gun offers possibilities.

Powder-Cutting Techniques

A comparatively recent process involving the use of iron and other powders is the flame-cutting technique originally introduced for cutting stainless steels and now usefully applied to a very wide range of materials, including not only steels of many kinds, but other metals and reinforced concrete. Wide use has been made of metal powders other than iron, particularly aluminium powder which can produce much higher temperatures. Many such metal mixtures have been patented. One patent B.P.696,840 covering the use of a powder combining the liberation of considerable heat with the formation of low melting point slag. It calls for a composition of 10–30% silicon and 5–20% aluminium, with the balance iron: the silicon is preferably added as ferro-silicon. The value of the powder as a heat liberator can be realised when it is mentioned that 1 kg. of the mixture liberates on combustion some 3,460 calories, whereas 1 kg. of iron powder only produces some 1,150 calories!

An interesting and valuable extension of the use of iron powder as a cutting agent has been its application to what is called powder-washing and powder-scarfing in the foundry. The speed with which material defects, sand inclusions and the rest, can be removed is phenomenal when compared with the time required for the normal chipping and cleaning. Two comparatively recent applications of powder-cutting may be mentioned; first the use of the aluminium iron powder for reducing heavy metal scrap to sizes suitable for furnace charging, and secondly, the use of a powder lance to start up cutting of carbon steel, thus eliminating the usual preheating before cutting which is normally required.

Bearing Surfaces

In the past two years there has been much steady progress alike in general technique and in the application of new methods and new materials. Mention may be made of one or two matters in connection with new bearing materials, for example, molybdenum disulphide. One novel application is covered by B.P.704,035, in which claims are made for bearings or like devices in which the parts move relatively in surface bearing contact. The bearing surface portions are made of hard metal, preferably tungsten carbide plus cobalt, and of iron or steel containing molybdenum disulphide, it being claimed that the materials have a very low coefficient of friction, high wear resistance and ability to run without lubrication at from 200 to 400° C. What may possibly be an even more important development is the use of Fluon, either for impregnating a porous metal base, or for sintering-on to provide a Fluon surface for bearings where a very low coefficient of friction is essential, and self-lubrication an advantage.

A new bearing surface is supplied by nylon powder[11] which is produced by a recently developed technique. The powder having particles below 10μ and known as Nylasint 66, is said to be suitable for processing by sintering techniques similar to those of powder metallurgy. It has also been suggested that 20% lead and the balance nylon powder is particularly interesting as an oil-less bushing.

A glance at recent literature on powder metallurgy shows no falling off of interest in the mechanism and control of the process of sintering, and an interesting mode of investigating the sintering process by making use of radioactive emanation has been recently described[12] in which radioactive material was introduced into the substance to be sintered and the α-radiations from the emanation of radioactive gaseous disintegration products was measured at various temperatures. In this way information was obtained in the form of a continuous record of the sintering process. Metal powders and mixtures and the compacted substances were compared. The apparatus is described and the results are presented in the paper referred to above.

The foregoing brief sketch of powder metallurgy during the past two years must, in the very nature of things, be incomplete and choosey. The technique is growing almost daily in breadth of scope and in the profundity of its investigations. It is difficult even to try to keep in touch with the major publications that are available. The Metal Powder Report which is published monthly in London usually carries some 20 pages of text and between 60 and 70 abstracts in each monthly number. So far as is possible it tries to abstract any and every important article in the major European languages. What it can and has achieved indicates in no uncertain way the widespread interest in the subject and the value of the communications which come in literally from the four corners of the globe and convey to us an overall picture of the field that is being covered and the type and quality of the original research which the subject has evoked.

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British Oilfield Equipment Co. Ltd.

HEENAN AND FROUDE LTD. and The Brush Group Ltd. announce that they have sold the whole of the issued share capital of British Oilfield Equipment Co. Ltd., which was jointly owned by them, to Cameron Iron Works, Inc., of Houston, Texas, U.S.A. The main business of the Company in recent years has been the manufacture and sale under licence of oil field equipment to the specifications and designs of Cameron Iron Works, Inc. In its capacity of a wholly-owned subsidiary of the latter, it will continue to operate under its present name, and Mr. Edward Benjamin will continue as Managing Director. Future plans include the expansion of manufacturing facilities and the manufacture and sale of additional Cameron products not at present being made in this country.

Meeting Diary

17th January

Institute of Metal Finishing—London Branch. "Anodic Oxidation of Copper," by Dr. S. G. Clarke and J. F. Andrew. "Sulphuric Acid Anodising to Specification DTD 910C," by V. F. Henley. Northampton Polytechnic, St. John Street, London, E.C.1. 6.15 p.m.

Institute of Metals—Sheffield Local Section. "Metallurgical Research in the Electrical Industry," by Dr. I. Jenkins. Joint Meeting with the **Sheffield Metallurgical Association** and the **Sheffield Society of Engineers and Metallurgists.** University Buildings, St. George's Square, Sheffield. 7.30 p.m.

18th January

Institute of British Foundrymen. "Design for Aluminium." Film by High Duty Alloys, Ltd. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m. Open invitation meeting.

Institute of British Foundrymen. "Some Metallurgical Problems in Casting Aluminium and Magnesium Alloys," by Dr. W. A. Baker. Coventry Technical College, Room A5. 7.30 p.m.

Institution of Mechanical Engineers. "Modern Trends in Controls for Boiler Plants." 1, Birdcage Walk, London, S.W.1. 6.45 p.m.

Society of Chemical Industry, Corrosion Group. "The Inhibition of the Attack of Metals by Acids," by T. P. Hoar. (Joint Meeting with the Birmingham and Midlands Section). Birmingham and Midland Institute, Paradise Street, Birmingham. 6.30 p.m.

19th January

Institute of Welding. "Argonaut Welding Process," by P. T. Houldcroft. Sun Hotel, Chatham 7.45 p.m.

Institute of Welding. "Welding in Shipbuilding," by E. Cuthbert. 39, Elmbank Crescent, Glasgow, C.2. 7 p.m.

Society of Instrument Technology. Joint Meeting with the Society of Glass Technology. "Temperature Measurement," by A. Wright. Stephenson Building, King's College, Newcastle-on-Tyne. 7 p.m.

Society of Instrument Technology. Visit of President. "The Physical Basis of Some New Measuring Techniques," by A. J. Young. Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m.

20th January

Institute of British Foundrymen. "Efficient Production Methods for Machine Tool Castings," by G. W. Nicholls. Hind Hotel, Wellingborough. 7.30 p.m.

Institute of Welding. "Automatic Arc Welding," by A. Bean and E. T. J. Harbron. College of Commerce and Technology, Leicester. 7.15 p.m.

Society of Chemical Industry, Corrosion Group. Conversazione and Exhibition. The main theme of the Exhibition will be "Corrosion Prevention in the Home." Battersea Polytechnic, London, S.W.11. 6.30 p.m.

21st January

Institution of Mechanical Engineers. Thomas Lowe Gray Lecture. "Some Factors in the Selection of Machinery for Cargo Liners," by Commander (E.) L. Baker, D.S.C., R.N. ret. 1, Birdcage Walk, London, S.W.1. 5.30 p.m.

West of Scotland Iron and Steel Institute. "Open-Hearth Furnaces—Design and Contruction," by J. L. Adamson. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

22nd January

Institute of British Foundrymen. "Some Aspects of Shell-Moulding," by D. F. Bailey. Gas Showrooms, Nottingham. 6 p.m.

Institute of British Foundrymen. C. R. Van der Ben and H. Haynes. Grand Hotel, Bristol. 3 p.m.

25th January

Institute of Welding. Discussion night and film on Automatic Welding. Great Northern Hotel, Leeds. 7.30 p.m.

26th January

Institute of British Foundrymen. "Melt Quality Tests": I.—Non-Ferrous. (a) Academic, by Dr. V. Kondic. (b) Copper Base, by A. French. (c) Light Alloys, by R. Crawford. Waldorf Hotel, London, W.C.1. 7.30 p.m.

Institution of Mechanical Engineers. "The Beneficial Use of Vibrations." 1, Birdcage Walk, London, S.W.1. 6.45 p.m.

Manchester Metallurgical Society. "Cathodic Protection," by Dr. W. F. Higgins. Lecture Room, Central Library, Manchester. 6.30 p.m.

27th January

Institute of Fuel. Joint Meeting with the **Coke Oven Managers' Association.** Paper on the Dutch State Mines. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institute of Metals—Birmingham Local Section. "Diffusion in Metals," by A. D. Le Claire. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

North East Metallurgical Society. "The Manufacture and Properties of Some Heavy Forgings," by Dr. H. H. Burton, C.B.E. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

28th January

Institute of British Foundrymen. "Defects in Vitreous Enamelled Castings," by E. R. Evans. Temperance Cafe, Lint Riggs, Falkirk. 7.30 p.m.

Institute of Metal Finishing. "Bright Nickel," by A. F. Brockington; "Barrel Polishing in General," by A. Brian. Grand Hotel, Sheffield. 6.30 p.m.

Institute of Welding. Joint Meeting with the **Institution of Structural Engineers.** "The Influence of Welding on Steel Building Structures," by S. M. Reisser. James Watt Institute, Great Charles Street, Birmingham. 6 p.m.

31st January

Incorporated Plant Engineers. "Reclamation of Worn Parts—Metal Spraying." Leeds University. 7.30 p.m.

Institute of Marine Engineers. "Metallurgy in Marine Engineering," by Dr. J. E. Garside. Old Swan Technical College, Liverpool. 7 p.m.

1st February

Institute of Metal Finishing. "Applications of Rubber and Plastic in Metal Finishing Plant," by E. W. Mulcahy. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 6.30 p.m.

Institute of Metals—Oxford Local Section. "Deformation of Metals at High Rates of Strain," by Prof. A. H. Cottrell. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Sheffield Metallurgical Association. "Recent Advances in the Radiography of Steel," by H. S. Pieser. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

2nd February

Institute of Welding. "Application of Welding in Power Stations", by M. P. Henzell. College of Technology, Manchester. 7.15 p.m.

3rd February

Institute of Metal Finishing. Subject to be announced. Dr. S. Wernick. Engineers' Club, Albert Square, Manchester. 7 30 p.m.

Institute of Metals—Birmingham Local Section. "The Effect of Trace Elements on the Properties of Iron and Steel," by Dr. N. P Allen. James Watt Memorial Institute Great Charles Street, Birmingham. 6.30 p.m.

Institute of Metals—London Local Section. "Tin and Tinplate," by Dr. W. E. Hoare. 4, Grosvenor Gardens, London, S.W.1. 6.30 p.m.

Institute of Welding. "Copper Welding Development," by L. Bernhardt. College of Technology, Portsmouth. 7 p.m.

Institute of Welding. "Electric Welding in a Large Shipbuilding Yard," by R. J. W. Rudkin. Mansion House, Portland Place, London, W.1. 7.30 p.m.

Institute of Welding. "Maintenance and Repair by Gas and Electric Welding," by A. Bishop and D. Jones. Norwich. 7.30 p.m.

Institute of Welding. "Researches into the Metallurgy of Welding at King's College," by R. N. Parkins and R. F. Tylecote. Mining Insitute, Neville Hall, Newcastle-upon-Tyne. 7 p.m.

Institute of Welding. "Welding at Atomic Projects," by I. H. Hogg. Cleveland Scientific and Technical Institution, Middlesbrough. 7.30 p.m.

Institute of Welding. "Welding Metallurgy," by H. O'Neill. Swansea Technical College, 7.15 p.m.

4th February

Manchester Association of Engineers. "Some Problems Associated with the Selection of Machine Tools for Heavy Engineering Production," by J. Henderson. Engineers' Club, Albert Square, Manchester, 2. 6.45 p.m.

7th February

Institute of British Foundrymen. "Bell Founding," by M. Howard. College of Technology, Pond Street, Sheffield. 7.15 p.m.

Institute of Welding. "Developments in Oxy-Acetylene Welding," by R. L. Fannon. Sheffield College of Commerce and Technology. 7.15 p.m.

8th February

Institute of Metals—South Wales Local Section. "Tool and Die Steels," by E. Johnson. Metallurgy Department, University College, Singleton Park, Swansea. 6.45 p.m.

Institute of Welding. "Recent Developments in Resistance Welding," by J. E. Roberts. Community Centre, Farnham Road, Slough. 7.30 p.m.

Sheffield Metallurgical Association. "Open Hearth Furnaces (v) Acid and Basic Bottoms." B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

9th February

Institute of Welding. "Hard Surfacing of Ferrous Metals," by M. Riddihough. Chamber of Commerce, Charlotte Square, Edinburgh. 7 p.m.

Institution of Engineering Inspection. Paper on "The Nimonic Series of Alloys," by a representative of Henry Wiggin and Co. Ltd. Compton Grange, Compton Road, Wolverhampton. 7.30 p.m.

Manchester Metallurgical Society. "Industrial Applications of Precious Metals," by Dr. J. C. Chaston. Lecture Room, Central Library, Manchester. 6.30 p.m.

10th February

East Midlands Metallurgical Society. Members Night. Short Papers. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of Welding. "Some Typical Details for Welded Building Structures," by H. Roscoe. 2, Savoy Hill, London, W.C.2. 6.30 p.m.

Liverpool Metallurgical Society. "The Thermochemistry of Alloys," by Dr. A. R. Harding. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

Society of Instrument Technology. "Plant Application of Analysis Instruments," by A. G. McLaren; "Gas Analysis by Infra-Red Absorption," by D. H. Whiting. Cleveland Scientific and Technical Insitution, Middlesbrough. 7.30 p.m.

11th February

Institute of Welding. "The Welding of Corrosion-Resisting Metals," by F. A. Ball. Colchester. 7.30 p.m.

14th February

Junior Institution of Engineers. "Blast Furnace Plant and Operational Problems," by E. A. Cotterill; "Electrical Equipment and Services for the Blast Furnace Plant at the Park Gate Iron and Steel Works," by H. Demaine. Livesey Clegg House, Sheffield. 7.30 p.m.

Institute of Metals—Scottish Local Section. "Some. New Developments in Nickel Alloys," by A. B. Graham and C. C Horne. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

Institution of Production Engineers. "The Manufacture of Engineers' Cutting Tools," by C. A. Grayson. The Grand Hotel, Sheffield. 6.30 p.m.

15th February

Institute of Welding. "Cracking in Welded Steel Joints," by K. Winterton. Victoria Station Hotel, Nottingham. 7.15 p.m.

Institute of Welding. "Welding for the Chemical Industry," by T. Williams. Liverpool College of Technology, Byrom Street, Liverpool. 7.15 p.m.

Sheffield Metallurgical Association. "Titanium," by Dr. N. P. Inglis. Joint Meeting with Royal Institute of Chemistry. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

16th February

Incorporated Plant Engineers. "The Protection of Structural Steel Against Corrosion," by K. H. Gibbons. Grand Hotel, Bristol. 7.15 p.m.

Institute of Fuel. "An Approach to Fuel Economy in a Large Engineering Works," by F. A. Worsley. Hotel Metropole, Leeds. 2.30 p.m.

Institute of Metals. Informal Discussion on "Non-Metallic Die Materials." Birmingham University, Edgbaston, Birmingham, 15. 10.30 a.m.

Institute of Welding. "Argonarc and Argonaut Welding," by W. Woollcott. Ashton-under-Lyne Technical College. 7.15 p.m.

Institute of Welding. "Modern Practice in the Welding of Pipes, Background and Present Trends," by E. Fuchs. 39, Elmbank Crescent, Glasgow, C.2. 7 p.m.

Society of Chemical Industry, Corrosion Group. Discussion on "Corrosion in the Home" opened by short papers:—"Some Corrosion Problems of the Household," by Mrs. A. Jackman; "Plumbing and Hollow-ware," by P. T. Gilbert; "Finishes for Domestic Equipment," by H. J. Sharp. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

Society of Instrument Technology. "Instrumentation for Mining Research in Strata Control and Ventilation." Prof. E. L. V. Potts to introduce paper by J. K. Dixon, D. Bannister and N. Tomlin. School of Mines, King's College, Newcastle-on-Tyne. 7 p.m.

Society of Instrument Technology. "The Progress of Temperature Measurement in Industry," by R. Postle. University Buildings, St. George's Square, Sheffield, 1. 7 p.m.

17th February

Institute of Welding. "Structural Steel Design," by R. J. Fowler. Great Northern Hotel, Leeds. 7.30 p.m.

In the New Year Honours List

Continued from page 2

B.E.M. (continued)

W. Jefferies, Senior Skilled Turner, Torrance and Sons, Ltd.
P. Kelly, Bricklayer's Mate, Ransomes and Rapier, Ltd.
A. E. Lake, Silversmith, Walker and Hall, Ltd.
W. Mathews, Carpenter, P. Gaylard and Son, Ltd.
A. Nightingale, Turner, British Insulated Callender's Cables, Ltd.
Miss J. Pirret, Fine Wire Mesh Weaver, Begg Cousland and Company, Ltd.
J. Riley, Foreman Assembly Department, British Timken, Ltd.
W. M. Robinson, Senior Foreman, R. B. Pulin and Company, Ltd.
E. Rooke, Works Technical Officer (Grade III), Fuel Research Station.
M. W. Wallace, Wire Rod Furnaceman, Guest Keen and Nettlefolds (South Wales), Ltd.
J. W. Wilson, Maintenance Engineer, Sheepbridge Steel Castings, Ltd.
F. A. Williams, Foreman, George Goodman, Ltd.
C. E. Withers, Chargehand Driller, Tyne Dock Engineering Company, Ltd.
J. M. Woodgate, Laboratory Worker "A," United Kingdom Atomic Energy Authority.
G. T. Wright, Ironfoundry Bench Moulder, R. W. Crabtree and Sons, Ltd.

NEWS AND ANNOUNCEMENTS

The Institute of Metals

Awards of Medals

THE COUNCIL OF THE INSTITUTE OF METALS has made the following awards of medals :—

The Institute of Metals (Platinum) Medal for 1955 to DR. C. J. SMITHELLS, M.C., F.I.M., Director of Research, The British Aluminium Co., Ltd., Gerrards Cross, in recognition of his services to metallurgical science, to the metal industries, and to the metallurgical profession.

The Rosenhain Medal for 1955 to DR. W. A. BAKER, F.I.M., Research Manager, The British Non-Ferrous Metals Research Association, London, in recognition of his outstanding contributions to knowledge in the field of physical metallurgy, with special reference to the influences of gases and shrinkage on the soundness of cast metals.

The W. H. A. Robertson Medal and Premium for 1954 to PROFESSOR H. FORD and MR. J. G. WISTREICH for their paper on " Problems of the Control of Dimension, Shape and Finish in the Rolling of Sheet and Strip and in the Drawing of Wire," published in the *Journal of the Institute of Metals*, 1954, vol. 82, pp. 281–290.

The Medal and Premium of 50 guineas, placed at the Council's disposal by W. H. A. Robertson & Co., Ltd., is awarded annually for the encouragement of the writing and publication in the Institute's *Journal* of papers on engineering aspects of non-ferrous metallurgy. MSS. of such papers should be addressed, in the normal way, to The Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1.

Northampton Polytechnic Courses

Two fifteen-week courses of interest to metallurgists open at the Northampton Polytechnic, St. John Street, London, E.C.1, towards the end of this month. Commencing on Monday, January 24th, is a course on " Heat Transfer, With Special Reference to Fuels " which has been specially arranged to meet the needs of fuel technologists, chemical engineers and metallurgists. The second course, on " Materials of Construction," covers both metals and non-metals, and will open on Thursday, January 30th. This course is designed for chemical engineers, metal finishing technologists, and all concerned with the construction of chemical plant ; special reference will be made to the corrosion resistance of the materials considered. The fees are : £1 10s. for the first course, and £1 15s. for the second. Further particulars can be obtained from the Principal.

Stress Corrosion Lecture Course

A SERIES of eight lectures by authorities in their particular fields on the effect of stress on the corrosion of metals will be given in the Department of Metallurgy at the Battersea Polytechnic, commencing on February 24th. The subjects to be discussed and the lecturers concerned are as follows : " Basic Structure and Deformation of Metals "—A. P. Miodowrik ; " Fatigue and Some of its Problems "—Dr. E. W. C. Wilkins ; " Fretting Corrosion " (2)—R. B. Waterhouse ; " Non-Ferrous Metals "(2)—Dr. F. A. Champion ; and " Iron and Steel " (2)—Dr. U. R. Evans.

The inclusive fee for these is two guineas and intending students should send the fee, together with name and address in block capitals, to the Secretary (Corrosion Course), Battersea Polytechnic, London, S.W.11, from whom further particulars may be obtained.

Domestic Corrosion Prevention Exhibition

A PUBLIC exhibition demonstrating materials and methods used in limiting corrosion in the home will be held in the Great Hall of Battersea Polytechnic, Battersea Park Road, London, S.W.11, on January 21st, 1955, from 10 a.m. to 4 p.m. Admission is free, and no ticket will be necessary. There will be a private showing the previous day to members of the Corrosion Group of the Society of Chemical Industry, who are organising the exhibition.

Metals have innumerable household uses. To mention only a few examples : outside the house, metal may be found in windows, rainwater gutters and pipes, gates and fences ; inside, there may be water cisterns, pipes, cooking vessels, cutlery, kitchen tools, stoves, washing machines, buckets and shovels. The uses are diverse but they have one feature in common : if the metal or the protection given to it is not well chosen, its appearance and usefulness will deteriorate through the action of corrosion.

The articles and utensils included in the display will fall into four categories—building materials, plumbing, domestic equipment and tools, and ornamental metalware, providing a comprehensive demonstration of the formidable extent of the corrosion problem and the protective methods being developed to combat it.

Institution of Metallurgists

Examination Results

THE following supplementary Pass List has recently been issued by authority of the Council of the Institution of Metallurgists :—

Fellowship.—F. CORRY.
Associateship.—E. STEIN.
Licentiateship.—K. G. C. BERKELEY and A. J. KING.

Industrial Radiography Materials Exhibitions

KODAK, LTD., have arranged a series of one-day exhibitions of materials and equipment for industrial radiography. Visitors will see examples of radiography's remarkable ability to expose faults in metals and in casting or welding techniques. There will also be on show the latest equipment—processing units, drying cabinets, illuminators, hangers, etc.—for radiography, by X-rays or gamma rays. Opportunities will also be afforded for the discussion of problems with experts from the Kodak Industrial X-ray School.

The London exhibition was held early this month, but the dates and venues for the remaining shows are as follows : BIRMINGHAM, Imperial Hotel, 28th January ; LEEDS, Queens Hotel, 16th March ; CARDIFF, Grand

Hotel, 31st March; MANCHESTER, Midland Hotel, 27th April; GLASGOW, Grand Hotel, 12th May; Newcastle, Royal Station Hotel, 19th May; and BRISTOL, Grand Hotel, 27th May.

Mond Nickel Fellowships 1954

THE Mond Nickel Fellowships Committee announces the following awards for 1954:—

M. BROWNLEE (Dorman, Long & Co., Ltd., Redcar). To study British, Continental and American hot and cold metal basic open hearth steelmaking with particular reference to furnace design and construction and factors affecting ingot quality.

R. D. BUTLER (Imperial Chemical Industries, Ltd., Liverpool). To study mineral dressing practice in Great Britain, on the Continent and in the U.S.A. and Canada, with particular reference to the design, layout and operation of small-scale mills.

F. B. PEACOCK (Dorman, Long & Co., Ltd., Middlesbrough). To study rolling mill operation and maintenance with particular reference to soaking pits, blooming mills and the production of universal beams, structural sections and rails.

A. M. SAGE (British Iron and Steel Research Association, London). To study the manufacture and fabrication of structural steels in the United Kingdom, Europe, U.S.A. and Canada.

Meeting to Discuss Shell Moulding

THE Association of Bronze and Brass Founders will hold a meeting at the Clarendon Restaurant, Hammersmith, London, W.6, on Thursday, 20th January, 1955, commencing at 7.15 p.m., at which a report on Shell Moulding will be given by Mr. J. L. Rice, B.Met., of the British Non-Ferrous Metals Research Association. Mr. Rice acts as Shell Moulding Advisor under the Advisory Service Scheme and has undertaken an investigation covering several months of the shell moulding process.

The meeting is open to all bronze and brass founders who may also take advantage of the services of Mr. Rice under the Advisory Service Scheme; applications should be made to the Secretaries of the Association of Bronze and Brass Founders, 69, Harborne Road, Birmingham, 15, from whom copies of the report may be obtained at a price of 5s. each.

Head Wrightson Scottish Acquistion

HEAD, WRIGHTSON & CO., LTD., Thornaby-on-Tees, annouce the acquisition of the whole share capital of F.P. Caird & Co., Ltd., 19, Waterloo Street, Glasgow. The name of the company is being changed to Head Wrightson (Scotland), Ltd. It is the intention of Head Wrightson to extend the design and sales staff of Head Wrightson (Scotland), Ltd. to offer a more complete range of services to their many customers in Scotland. The new directors of the company are Sir John Wrightson, Bart., Mr. Peter Wrightson and Mr. J. W. Wardell. Mr. J. T. Young will be the official responsible for the operation of the Glasgow office.

B.R.S. Conditions of Carriage

BRITISH Road Services have decided that, as from January 1st, 1955, in cases where loss, damage or destruction is caused to merchandise by fire or explosion whilst in transit, they will not invoke proviso (1) to Condition 4 of their Conditions of Carriage; and will not, therefore, seek relief from such liability solely on the ground that they have exercised all reasonable foresight and care in the carriage of the merchandise. It is felt that this concession will be of considerable value to traders.

Personal News

MR. D. N. DE MATTOS has been transferred from the London Office of The British Thomson-Houston Co., Ltd., to the B.T.H. District Office in Bristol, where he is Sub-District Manager. MR. B. BARTON, who until recently was on the staff of the B.T.H. Manchester Office now holds a commercial engineering appointment at Crown House, Aldwych, W.C.2, and MR. E. R. SEADON who for six years has been on the lighting-engineering staff of the Company, has been posted to the Industrial Sales Division of the London Office as a Commercial Engineer.

LYMINGTON BOROUGH COUNCIL have unanimously decided to confer the Freedom of the Borough on MR. J. HOWLETT, Chairman and Managing Director of Wellworthy, Ltd., the piston and piston ring manufacturers, in recognition of "his eminent services to the Borough and his outstanding contribution to its welfare and development over a period of many years."

MR. W. H. SMITH has resigned his appointments as Managing Director of The Falkirk Iron Co., Ltd., and of Callendar Abbots Foundry Co., Ltd., and has been succeeded by MR. R. G. SINCLAIR. Mr. Smith will continue as Chairman of the Boards of the two companies.

SIR CHARLES BARTLETT, Managing Director of Vauxhall Motors, Ltd., for 23 years and Chairman since, 1953, has retired from the Board, which he has served eith great distinction over the past 25 years.

MR. A. E. HOBSON, until recently Assistant Home Sales Manager of Baird and Tatlock (London), Ltd., has been appointed Manager of the new Northern Division of the B.T.L. Group. Between 1946 and 1950, he was the Technical Sales Representative of the firm in the North of England.

MR. H. C. THOMAS, Director and Secretary of Northern Aluminium Co., Ltd., is being accorded retirement status by private arrangement with the Company. Prior to joining Northern's London Office Staff in 1925, Mr. Thomas was employed as an accountant with the Company's auditors. He was appointed Secretary in 1929 and was given a Directorship in 1932. In 1942, he was made a Director of Aluminium Laboratories, Ltd.

MR. E. H. BALL, a Director of Associated Electrical Industries, Ltd., and Managing Director of The British Thomson-Houston Co., Ltd., has been elected Chairman of Birlec, Ltd., which was recently acquired by A.E.I. Also elected to the Board have been MR. W. W. VINSEN, the B.T.H. Director of Manufacture, and MR. E. S. LITTLE, Comptroller and Secretary of B.T.H. These three new directors join the existing executive directors, MR. GEORGE P. TINKER (Managing), MR. T. G. TANNER and MR. J. H. CROSSLEY.

BABCOCK & WILCOX, Ltd., announce that, in view of their expanding activities in Latin America, MR. A. S. PEACOCK has been appointed as Manager for that territory, with general responsibility for the Company's business there, including factory development in Brazil and co-ordination of policy.

MR. A. G. STEWART, Chairman and General Managing Director of Stewarts & Lloyds, Ltd., has been appointed President of the British Iron and Steel Federation in succession to MR. G. H. LATHAM, Chairman and Managing Director of Whitehead Iron & Steel Co., Ltd. SIR ERNEST LEVER, Chairman and Chief Executive of Richard Thomas & Baldwins, Ltd., and The Steel Company of Wales, has been appointed President Elect of the Federation.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce the appointment of MR. P. R. DUNN, as Chief Engineer. He succeeds Mr. D. T. Hollingsworth who has recently been appointed to the Board of the Company.

MR. G. E. G. HOPE-JOHNSTONE, Sales Director of the Regent Oil Co., Ltd., has resigned from the Board of the Company to take up the position of Vice-President of Trinidad Leaseholds (Canada), Ltd. He is succeeded as Sales Director of the Company, and on the Board by MR. J. A. J. NICHOLAS, Regent's General Sales Manager. The functions of the General Sales Manager are now carried out by MR. O. H. FISH, as Dealer Sales Manager, and by MR. G. W. LIMMER, as Commercial Sales Manager. Mr. Limmer is succeeded by MR. H. J. TANNER as London Branch Manager of the Company, and Mr. C. D. B. FREELAND, Deputy Branch Manager of Regent's Western Branch takes up the position of Western Branch Manager in succession to Mr. Tanner.

MR. T. ALLEN has been appointed to the Board of G.W.B. Furnaces, Ltd., and will be the administrative Director in charge at the Head Office at Dudley. Mr. Allen joined the company in 1934, and has been General Manager since 1948. A further appointment is that of MR. A. V. FRANCIS to the position of Chief Engineer. Mr. Francis will be in charge of furnace design and sales.

SUNVIC CONTROLS, LTD., announce the appointment of Mr. G. G. HARRIS of "Lydstep," 20, Lawn Road, Rowley Park, Stafford (Tel.: Stafford 1764) as their Midlands representation for process control. Sunvic representatives in the Midlands for scientific and industrial instruments will remain with Mr. G. R. PEEKE, of 17, Stratford Road, Birmingham, 11 (Tel.: Victoria 1076).

DR. MAURICE COOK (Joint Managing Director of the Metals Division of Imperial Chemical Industries) has been elected Chairman of the British Non-Ferrous Metals Research Association in succession to the Hon. R. M. PRESTON who retired from office at the end of last year.

THE Directors of H. J. Enthoven & Sons, Ltd., announce that MR. A. R. MATHIAS has been elected a Director of the Company in place of MR. R. T. DE PROIX who has resigned from the Board.

MR. J. S. JEFFREY has resigned his position as Joint Managing Director and has retired from the Board of Woodall-Duckham Construction Co., Ltd. He will retain his Directorship of the Parent Company—Woodhall-Duckham, Ltd.—as well as the other Directorships which he holds on behalf of the Woodall-Duckham Group, namely, Chairman of Nederlandsche Overnbouw Maatschappij N.V., Deputy Chairman of W. J. Jenkins & Co., Ltd., and Director of The International Furnace Equipment Co., Ltd. Mr. Jeffrey has been succeeded as Director by MR. J. SIMPSON, who joined the Company in February, 1926, and was for many years on the sales side of the Company's business. He joined the Board in 1946 and for the past nine years has been responsible for organising the provision of supplies and services to enable the Company to carry out a rapidly expanding construction programme.

Obituary

WE regret to record the death of the following:

MR. ERNEST MILLINGTON, who died at his home at 27, Manor Road, Borrowash, Derby, at the age of 81. Mr. Millington, who was born in Manchester, commenced his railway career at the Horwich Works of The Lancashire and Yorkshire Railway Company. He studied mechanical engineering at Horwich and at Manchester University, and was appointed Personal Assistant to the Works Superintendent at Horwich, where he was engaged on the investigation of metallurgical problems. In this capacity, he re-organised the plant and processes, and compiled mechanical and physical specifications for ferrous and non-ferrous materials used in the manufacture of locomotives and rolling stock. He also did much useful pioneering work in the investigation of water softening processes designed to reduce the formation of scale in locomotive boilers. Although Mr. Millington was a man of many and widely divergent interests, his chief interest lay always in railway work, and in 1912, he was appointed as Works Metallurgist to The Midland Railway. He subsequently became Chief Works Metallurgist for The London Midland and Scottish Railway, and held this position until his retirement in 1936. After his retirement, Mr. Millington did valuable work as Consultant Metallurgist to the Incandescent Heat Co., Ltd.

MR. HAROLD BARKER, Manager of the Newcastle Office of Babcock & Wilcox, Ltd., who died suddenly at the age of 49. Mr. Barker had been with Babcock & Wilcox since 1921, except for a short period in 1927 and 1928, which he spent in the Merchant Navy on the engineering staff of the *Berengaria*. He had had extensive sales experience in Leeds and London and was appointed Manager of the Newcastle Office in 1950.

MR. ARTHUR SCRIVENER, with whose sudden death at the age of 57, there passes a notable personage in the English machine-tool industry. After a number of years association with the B.S.A. organisation, in 1932, he established, in Birmingham, his own works and company (Arthur Scrivener, Ltd.), of which he was Managing Director. There he concentrated mainly upon the manufacture of centreless grinding machines, in which branch, during the succeeding years, he was responsible for many innovations and improvements, particularly in connection with automatic operations.

MR. V. W. GREEN, Branch Manager of British Insulated Callender's Cables, Ltd., in Gloucester, who was 60 years of age. Mr. Green joined the company in July, 1925, as a representative at the Cardiff office. In 1931, he was promoted and took charge of the newly formed branch office at Gloucester. He played an active part in local affairs and at the time of his death was a member of Gloucester City Council.

MR. HOWARD FOULDS, who was for 26 years Secretary of the former Callender's Cable & Construction Co., Ltd. Mr. Foulds, who died in his 86th year, retired on the amalgamation of the company with British Insulated Cables, Ltd., in 1945.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Diffuse Reflection Glass

IT has long been realised that ordinary clear glass for instrument dial covers leaves a lot to be desired in service due to the incidence of reflection from the glass. In power stations and elsewhere, it is a common practice for many instruments to be mounted on a control panel and because of the glare from the lighting points, or wrong positioning of the instrument panel in relation to windows, the clear glasses have a mirroring effect, often making it impossible to read the dials at certain angles. Changing of position in order to read the dials correctly may not always be possible if the observer is some distance in front of the panel and has to control the machinery at the same time. This handicap from clear glass can often mean inefficient control of the plant. After a long series of experiments, Pilkington Brothers Ltd., have produced a glass with both surfaces lightly obscured which successfully mitigates the nuisance of reflection without actually reducing the amount of light reflected. It is available in substances 2·6/3·2 mm. and upwards, and at present in sizes up to 18×12 in. and can be obtained toughened if required. Bent glass to approved curves is available as well as flat glass. The glass is particularly suitable for meter and gauge glasses where the observer is positioned at some distance from the instrument panels and is unable to move into a position to avoid reflections. It only functions satisfactorily so long as the dial face of the instrument is reasonably close behind the glass.

Pilkington Brothers Ltd., St. Helens, Lancs.

Electronic Recorder

THE versatility and high sensitivity of the new Cambridge Electronic Recorder make it suitable for a wide variety of applications. It is of the continuously balancing type, the rebalancing of the measuring circuit being effected by means of a small servomotor. Any voltage error due to unbalance is converted into a 50 c/s signal of appropriate phase and, after electronic amplification, is applied to the servomotor to drive it in such a direction as will restore balance. Damping of the recorder movement is obtained by feeding, to a suitable point in the amplifier, the voltage from a tachometer generator coupled to the servomotor. For most applications the instrument is supplied as a recording potentiometer for the measurement of small D.C. potentials, but alternatively the measuring circuit can be arranged as a low resistance current measurer, as a D.C. bridge, or, with certain limitations, as an A.C. bridge or potentiometer.

The slide wire current is normally obtained from an air depolariser dry cell mounted in the instrument, and is standardised manually against a Weston normal cell. This simple arrangement is satisfactory for most purposes, but where it is necessary to ensure standardisation over long periods, the dry cell may be replaced by a mains-operated stabilised power unit. The current from this unit is standardised as above, and will thereafter remain constant to within about 0·1% for periods of a month or more.

Single-point models use a syphon type pen and provide a continuous line record, whilst multipoint records are made with a turret marker. Either 2, 3, 4 or 6 circuits are selected in turn by the recorder mechanism and the records printed in distinct colours at the rate of 10 points per minute. Where necessary, the instrument can be provided with a three-speed gearbox giving chart sheets in the ratio 1 : 2 : 4.

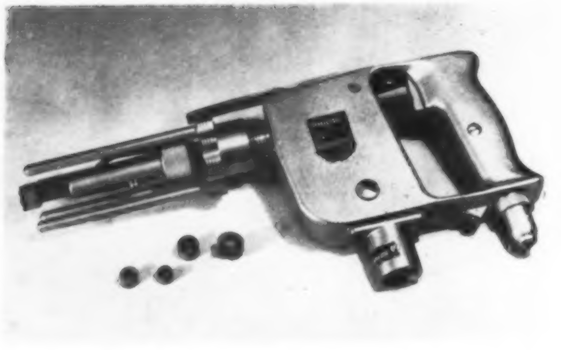
The electronic recorder may be adapted for use as an automatic controller, in which case its high speed of response reduces controller lags.

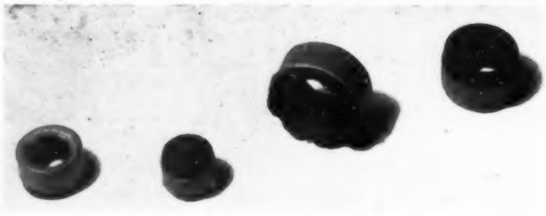
Cambridge Instrument Co. Ltd., 13, *Grosvenor Place, London, S.W.*1.

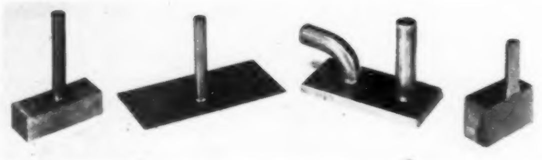
New Stud-Welding Process

THE development of a new stud-welding process has resulted, in some degree, from a close study of the "contact" arc-welding method introduced by Philips towards the end of the war. In this, thickly-coated, semi-conducting electrodes are used, greatly simplifying ignition and re-ignition ; the stud-welding cartridge was designed upon the "contact" electrode principle. The stud rests upon a constriction in the cartridge, and during welding that part of the cartridge upon which the stud rests is fused away, releasing the stud which is then pressed into the weld pool. Special studs are not necessary in this process.

The welding gun is adjusted to the length of the studs to be used, by a coarse adjustment, and the stud is then clamped into the stud-holder by spring pressure. Fine adjustment may be effected so that the stud protrudes 0·2–0·5 mm. from the plane of the tips of the support. A welding cartridge is then pushed on to the stud and the gun is placed on to the workpiece. As the gun is pressed on to the plate, the stud-holder is







Above—Philips stud welding gun.

Top right—A selection of welding cartridges.

Bottom right—Specimen welds, including sectioned and hammered samples.

pushed upwards and a spring is compressed. The current is turned on by a micro-switch in the handle of the gun, the arc is ignited and, after that part of the welding cartridge upon which the stud rests has been fused away, the stud is pressed upon the work-piece by the spring. A stop ensures uniformity of the distance by which the stud is pressed into the weld pool. After the weld has been completed the switch is released and the short-circuiting current is switched off. The gun is removed from the work-piece together with the remains of the welding cartridge. Welding can be carried out in both the vertical and overhead positions.

An important feature of the new system is that A.C. current may be used, thus permitting the use of ordinary welding transformers (at least 70-volt open circuit voltage). The primary side is operated by a magnetic switch. The micro-switch in the gun operates the secondary coil, via a transformer, which reduces the voltage to the safe level of 24 volts. In its turn, the magnetic switch actuates the primary of the welding transformer.

The process is designed, primarily, for the welding of unalloyed steel. Depending upon requirements, pre-heating is recommended when using hardenable steels.

A simple method of testing the strength of the weld is by hammer blows. Ordinary steel studs, it is found, can be bent through 90° without fracturing. With more brittle metals a smaller plastic deformation occurs. Normal tensile tests show that fracture usually occurs outside the weld.

Stud-welding cartridges are, at present, made in four diameters, $\frac{1}{2}$, $\frac{3}{8}$, $\frac{5}{16}$ and $\frac{1}{4}$ in. (12·7, 9·55, 7·9 and 6·35 mm.). Wide deviation from these dimensions should be avoided, and the following tolerances are permissible: $\frac{1}{2}$ in. studs, 0·3 mm.; $\frac{3}{8}$, $\frac{5}{16}$, $\frac{1}{4}$ in. studs, 0·2 mm. When normal welding transformers are used, the following current settings should be used for relatively thick plate: $\frac{1}{2}$ in. studs, 750 amp.; $\frac{3}{8}$ in. studs, 500 amp.; $\frac{5}{16}$ in. studs, 450 amp.; and $\frac{1}{4}$ in. studs, 325 amp. For thin plates a lower current setting must be used.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Semi-Automatic Ejecta Plate Magnet

The application of Rapid permanent plate type magnetic separators already covers a wide industrial field, for they possess strong pulling power which enables them to extract tramp iron and ferrous particles from a wide variety of powdered, granular and fibrous materials.

The cleaning of collected tramp iron and ferrous particles from permanent magnets has, however, always been a problem, but the new Rapid Ejecta Plate has been specially designed to facilitate the removal of such material. The unit is compact and is quite easy to install as was its predecessor, the Magnaplate. The face has two auxiliary poles hinged and held magnetically in position, and on swinging the plate clear of the chute for cleaning (2), two cams operate against the face plate initially breaking the magnetic circuit, thus permitting the face plate to be easily swung clear of the magnet unit (3), when the auxiliary poles, no longer under magnetic influence, allow the collected iron to fall.

Rapid Magnetic Machine, Ltd., Lombard Street, Birmingham, 12.

CURRENT LITERATURE

Book Notices

THERMAL CONDUCTIVITY OF METALS AND ALLOYS AT LOW TEMPERATURES

(A review of the literature by R. L. Powell and W. A. Blanpied. National Bureau of Standards Circular 556, 68 pp. Government Printing Office, Washington 25, D.C. 50 cents. Foreign remittances must be in U.S. exchange and should include an additional one-third of the publication price to cover mailing costs.)

ACCURATE data on the thermal conductivity of construction materials at low temperatures are essential in the design of cryogenic equipment. Such data on pure metals also have important applications in basic physics. The present Circular was prepared by the NBS-AEC Cryogenics Laboratory of the NBS Boulder Laboratories to satisfy the need for a complete and authoritative compilation of the useful but widely scattered data on thermal conductivity at low temperatures. It includes tables of measured values of thermal conductivity for metals and alloys from room temperature down to approximately 0° K. The more extensive and important data are plotted in 48 graphs. The data are essentially complete for literature references from 1900 to early 1954. For comparison, several graphs and tables are given for some representative dielectrics.

METAL STATISTICS (1938, 1946–1953)

42nd Annual Issue. 200 pp. Published in English by Metallgesellschaft A.G., Reuterweg 14, Frankfurt-am-Main.

THIS year sees the resumption of the publication of statistical tables on the non-ferrous metals by Metallgesellschaft A.G., Frankfurt-am-Main, the information included in the 42nd issue covering the year 1938, and 1946–53. Following a world survey of production and consumption of aluminium, lead, copper, zinc, tin, cadmium, magnesium, nickel, mercury and silver, there is a comparison of production and consumption of aluminium, lead, copper, zinc and tin by continents extending as far back as 1909. The detailed statistics, country by country, and metal by metal, include particulars of production and consumption, together with figures for imports and exports according to country of origin and destination, respectively. The import and export figures are also broken down to indicate the types of product concerned, e.g., sheet, rod, tubes, wire, chemicals, etc. Finally, prices are given from 1900 onwards (in most cases) for Germany, United Kingdom and United States of America, with monthly averages for the post-war years in the case of lead, copper, zinc and tin. The 43rd issue of "Metal Statistics" will not appear until April, 1956, and it is hoped to publish succeeding issues in the first half of each succeeding year.

CATHODIC PROTECTION AGAINST CORROSION

Proceedings of Symposium held in November, 1953. London, 1954. Society of Chemical Industry, Publications Department, 9/10, Savile Row, London, W.1. 12s. 6d.

IN November, 1953, the Corrosion Group of the Society of Chemical Industry organised a Symposium on Cathodic Protection. Contributions were made from authors with a great wealth of experience of this method of preventing corrosion, gained in different fields and in several countries.

The seven Papers presented have already been published in *Chemistry and Industry*, but they have now been collected in one volume, together with the report of the contributions to oral and written discussion made by many other authorities. The combined publication constitutes an up-to-date survey of the practical applications of cathodic protection and provides a useful guide to what can be achieved by it.

The Papers included are: "Cathodic Protection in Relation to Engineering Design," by K. A. SPENCER (Great Britain); "The Effect of the Composition of Magnesium Anodes on their Efficiency," by M. OUDEMAN (Holland); "Development of Cathodic Protection in Belgium," by A. WEILER (Belgium); "Economic Aspects of Corrosion Control," by D. H. LEWIS and O. C. MUDD (United States of America); "Cathodic Protection and Corrosion Control in the Middle East," by W. C. R. WHALLEY (Iraq); "Cathodic Protection: Its Application to Canadian Marine Vessels in Active Service," by K. N. BARNARD (Canada); "Application of Cathodic Protection to Ships and Establishments of the Royal Navy," by J. T. CRENNELL (Great Britain).

This volume should prove of great value to all who are concerned with the upkeep of the numerous types of structure to which cathodic protection can be successfully applied, such as the underwater parts of ships and marine installations, pipelines in water or underground, the interiors of large vessels holding electrolytes, or their exteriors in contact with the ground.

DETERIORATION OF MATERIALS—CAUSES AND PREVENTIVE TECHNIQUES

835 pp., 255 illustrations, 1,500 references and comprehensive subject index. Prepared under the joint auspices of the Prevention of Deterioration Center (National Academy of Sciences—National Research Council) and the Services and Technical Committee of the U.S. Department of Defense. Compiled by 24 specialist contributors and edited by Glenn A. Greathouse and Carl J. Wessel, Director and Associate Director, respectively, of the P.D.C. New York, 1954. Reinhold Publishing Corporation. $12.

ALTHOUGH there are already available many books on the preservation of specific materials such as wood, metals, textiles, paints, and so on, this is the first to bring under one cover a comprehensive analysis of deterioration problems and a survey of techniques presently available for preserving many of the materials in common use to-day. The unusual breadth of subject matter now presented was made possible through the co-operation of a great many individuals and numerous organisations, inside and outside the Federal Government, who contributed special information and latest research findings. As is the case with many Academy-Council activities, the new volume is a result of the special kind of co-ordination for which the National Academy of Sciences was established.

Available information on deterioration prevention falls chiefly into two categories, the first embracing the basic scientific principles concerned, and the second covering applications of these principles in practice. The text of the new volume has been organised accordingly. Part I deals with the basic causative agents in materials deterioration—the climatic factors and the chemical,

physical, and biological agents of deterioration as related thereto. Part II is concerned with the action of these agents on materials of various kinds and with specific methods of deterioration prevention. Part III discusses the protection of certain important assemblies of electrical, electronic, optical, and photographic equipment. And finally Part IV covers some special aspects of preservation, including dehumidification of warehouses and ships, approved methods of packaging, and the toxicological aspects of preservatives. Appended is a short analysis of the system of Government specification numbers.

This book stems originally from the difficulties brought sharply into focus early in World War II, when the deterioration of vast quantities of military goods and equipment posed a problem of serious strategic importance. To meet that urgent need, there was organised early in 1940 the Joint Army-Navy Deterioration Steering Committee under the National Defense Research Committee and, later, under O.S.R.D., the Tropical Deterioration Information Center. With the end of the war and the disestablishment of O.S.R.D., the work toward deterioration prevention, like certain other wartime activities, was seen to merit continuation into the peace. Consequently, with the support of the Army, the Navy, and the Air Force, the Prevention of Deterioration Center was organised within the framework of the Academy-Council to serve in a consultative capacity and as a clearing-house for information as it issued from the laboratories engaged in research. Decision to publish in book form the data so collected had the intent of making readily accessible a body of knowledge otherwise mostly available in reports of limited distribution only.

Although the present volume was intended originally to be of special use to the military services in preserving goods and equipment, the subject matter obviously will be of substantial importance to manufacturers generally, to shippers and transportation agencies, to insurance carriers, and to all others concerned with the maintenance of goods of all kinds.

Trade Publications

AFTER the recent wet summer, it is a little difficult to appreciate that the water which is vital for growing crops must sometimes be supplied by irrigation. The use of aluminium pipes and fittings for this purpose is dealt with in an illustrated leaflet issued by Aluminium Union, Ltd., London, W.C.2, in which the advantages of aluminium in respect of lightness and corrosion resistance are demonstrated. A further leaflet concerns the use of aluminium for building small craft such as dinghies, fishing boats and launches, whilst the use of flat and coiled aluminium sheet for roofing is featured in a third.

FIVE new leaflets issued by W. Canning and Co. Ltd., Birmingham, 18, cover the Company's comprehensive range of metal cleaners developed specifically for the electroplating and metal finishing industries. These cleaners are intended for the removal of grease or oil left on surfaces after machining, stamping, spinning, pressing or polishing. Zonax is a general purpose hot cleaner for all metals including light alloys and zinc base diecastings, whilst Ferrax is a heavy duty hot cleaner for greasy iron and steel. Kleenax, a cold electrolytic cleaner for non-ferrous metals, is intended as a final cleaner after preliminary degreasing has been carried out in Zonax. It eliminates scouring, and does not impair the brilliance of polished surfaces. For iron and steel, the counterpart of Kleenax is Klenewell, a cold electrolytic cleaner which does not cause embrittlement of hardened steel, and dissipates hydrogen occluded by the metal during previous processes. The latest addition to the Canning range of cleaners, is Unimax, a universal cleaner which can be used hot or cold, with or without current.

A LOT has been heard in recent years about big castings, but much less about the small ones which have a much wider field of use. The articles shown in a leaflet recently issued by the Zinc Alloy Die Casters Association, entitled "Big Savings with Small Zinc Alloy Die Castings," are a graphic illustration of the many advantages offered here by the pre-eminent castability of the zinc alloys—speed of production, economy of material and above all, the saving in machining and handling costs. The zip fastener slider is a familiar example of a small zinc alloy die casting, but the leaflet also shows gear wheels, wing-nuts, rivets, control knobs, ornaments and complicated parts of toys, clocks, and other small mechanisms. Copies may be obtained from the Association at Lincoln House, Turl Street, Oxford.

ELECTRO-ALLOYS, LTD., have for a number of years served those branches of the electrical and allied industries in which the use and application of tungsten and molybdenum are a recognised necessity. A new brochure produced by the company illustrates and describes a large section of the manufacturing programme, the text being in English, French and German. The items featured include electrical contacts; lead-wires for glass-to-metal seals; tungsten welding electrodes for inert gas shielded arc welding; molybdenum tubes; fixed and rotating anodes for X-ray tubes; tungsten and molybdenum heaters for vacuum metallising plant; components for the electronic and related industries; and spark gap electrodes.

EUROPEAN Zinc Alloy Die Casting Bulletin, the first number of the English Edition of which has recently appeared, is the result of close collaboration between the Zinc Development Association, the Commission Technique des Alliages de Zinc, the Zinkberatung, and S.A. Montevecchio, who will prepare successive identical issues to be translated for wide circulation in English, French, German and Italian. The first issue is devoted to the use of zinc alloy die castings in the European automobile industry. Subsequent numbers will concentrate on other important fields in which the castings are used.

TWO recent publications available from Enthoven Solders, Ltd., 89, Upper Thames Street, London, E.C.4, deal, respectively, with solder products and a new Superspeed soldering iron. The latter heats up from cold in six seconds, and can be used on a 2·5–6·3 volt supply. It is more powerful than a conventional 150-watt iron and equally suitable for light wiring work or heavy soldering on chassis. The solder product catalogue details the various grades and forms of solder manufactured by the Company, from solid and flux cored wire to solder paints, and from cored and solid solder preforms to solid solder sticks, strip and ingot

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

JANUARY, 1955 — Vol. LI, No. 303

Segregation in Cast Aluminium Alloy Spectrographic Electrodes

By W. E. Mew,* F. H. Smith† and J. Wood‡

The use of the direct reading spectrograph for the analysis of aluminium casting alloys has emphasised the importance of avoiding segregation in the cast spectrographic samples. This paper presents the results of an investigation into segregation effects in flat and pencil type chill cast samples, and compares the reproducibility of analytical results obtained with cast and wrought electrodes.

THIS paper is an account of an investigation into difficulties experienced in the spectrographic analysis of aluminium alloys which are caused by segregation in the spectrographic samples. It has long been recognised[1, 2, 3] that segregates are a potential source of error, but it has been assumed that in practice an adequate degree of homogeneity is achieved by casting thin samples in metal moulds. This investigation, however, shows that considerable segregation is present in the types of cast spectrographic samples commonly employed, and that under certain circumstances it may significantly affect the accuracy of the analytical results.

Since this work was commenced, about two and a half years ago, the problem of segregation in electrodes has received increasing attention from other investigators, owing to the increased accuracy and wider range of determinable compositions made available by direct reading spectrographs. One or two of the new forms of electrodes suggested by these investigators have been included in some of the experiments described. More recently an attempt to avoid segregation problems by using molten electrodes has been reported.[4]

The difficulties which caused the present investigation to be undertaken occurred in the laboratory of International Alloys, Ltd., where the practice is to spark a cast plate sample against a graphite counter electrode. Later, the ALAR Spectrochemical Sub-Committee became interested in the general problem of segregation, and a more comprehensive programme of experiments with both pencil and flat electrodes was devised, and the work carried out in the laboratories of the Sub-Committee members. The investigation described is by no means complete, but it is thought that publication of this interim account will be of immediate interest to other users of spectrochemical analysis methods.

Segregation in Plate Samples

It was noted that there was a tendency for the values found chemically in certain aluminium alloys to differ consistently from those obtained spectrographically by sparking cast plate electrodes. Furthermore, with these particular alloys it was found impossible to maintain a straight line calibration curve when the spectrographic density ratios were plotted against contents for the standard samples. These anomalous results, it was thought, could only be explained by non-uniformity in composition throughout the electrode, which was accordingly examined for evidence of segregation.

Fig. 1.—Casting for flat type of electrode. ×$\frac{3}{5}$

The casting from which the electrode is produced is illustrated in Fig. 1. It is vertically poured in a cast iron book type mould and is a plate approximately $\frac{3}{8}$ in. thick, $1\frac{1}{2}$ in. by 4 in. in area, with a feeder head of

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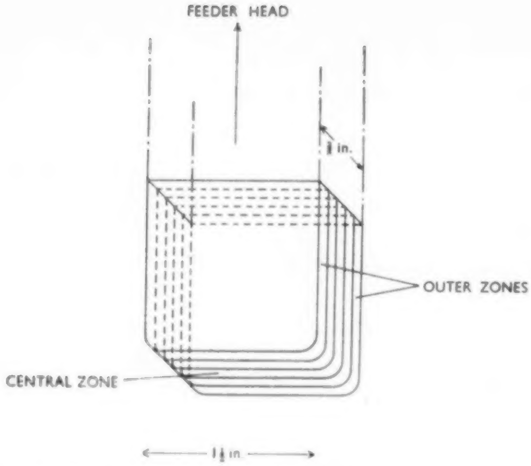

Fig. 2.—Diagram showing method of sampling for layer analyses.

greater section. Only the lower $1\frac{1}{4}$ in. of the casting is used for the electrode and it was the practice in routine spectrochemical analysis to remove only a very thin layer from the surface before sparking. The standard samples, on the other hand, were machined many times to provide new sparking surfaces, and the area excited may have varied in position from a few thousandths of an inch to 0·18 in. below the cast surface.

To determine whether these surfaces differed significantly in composition, chemical analyses were made of samples obtained by machining away successive layers as illustrated in Fig. 2. Five such layers were examined in cast electrodes of the Al-Mg-Si alloy HE10, and the Al-Cu-Mg alloy L50 for the elements copper and silicon, and the values obtained were plotted in the form of graphs. The curves in Fig. 3 represent typical segregation patterns for this shape of casting. They reveal a difference in the content of the two elements, between the outside and the centre of the casting, of 5–10% of the mean content. These variations in composition offer a satisfactory explanation of the anomalous results referred to earlier and the difficulty of obtaining a straight line calibration curve, since, in practice, the depth of machining was not standardised, and with the standards repeatedly used for calibration, the sparking surface could vary in time over a considerable depth of the electrode. It was realised that the composition over any one surface would also change as the edge was approached, but it was considered that the error introduced by this edge effect would not be large enough to justify a more elaborate sampling procedure in this investigation. (This variation within any one surface is referred to later.)

Practical Counter Measures

Having established the occurrence of segregation in this type of electrode, it became necessary either to change to a form of sample which would be substantially free from segregation, or to use the existing sample in such a way that composition variations, as a serious source of error, would be eliminated. It was apparent from an examination of Fig. 3 that the portion of the sample situated between 0·060 in. and 0·120 in. from the cast surface represented the average composition of the sample, and that the variation in composition through its thickness was comparatively small. On this basis a simple and immediate solution was evolved as an answer to the second of the above alternatives, and the following modified procedure was introduced for routine samples. The outer $\frac{1}{16}$ in. layers were machined from the sample and only the second layer of $\frac{1}{16}$ in. used for sparking. In each surface within this layer, sparking was confined to two positions each halfway between the edge and the centre of the plate to avoid a possible edge effect. When the whole of this layer was machined away in the course of time by resurfacing after sparking, as in the case of standards, the remainder of the electrode was discarded. The adoption of this procedure, which has since been strictly followed, resulted in a marked improvement in the agreement between chemical and spectrochemical results, and also enabled straight line calibration curves to be obtained from the standards.

Segregation in Other Flat Samples

The problem of modifying the plate casting to reduce segregation, or of developing a new electrode casting substantially free from segregation, remained to be solved. It is the practice in the laboratories of some producers of wrought aluminium products to use standards produced from wrought, e.g., extruded bar, thus partially overcoming this problem. This method, however, is not a complete solution since (*a*) it is still necessary to be certain that the routine samples themselves, which must be cast, are consistent in their segregation behaviour from one to another, and this becomes increasingly important as high alloying contents are analysed spectrographically ; and (*b*) where the alloys to be analysed are casting alloys, it is not always possible to obtain standards in wrought form.

As a first attempt at improving the flat casting, a number of plates similar to that illustrated in Fig. 1 were cast with thicknesses of $\frac{1}{4}$ in., $\frac{5}{16}$ in and $\frac{3}{8}$ in., and each was chemically analysed in layers as described earlier for the normal electrode casting. The results for the elements copper and silicon in a duralumin alloy are shown graphically in Fig. 3, and it can be seen that no diminution of the amount of segregation was achieved by reducing the sample thickness from $\frac{3}{8}$ in. to $\frac{1}{4}$ in. Similar results were obtained with H10 alloy.

Some attempts were also made, using the Quantometer, to compare the degree of segregation in the plate electrode with that of other forms of point-to-plane electrodes. Preliminary tests were carried out with a vertically cast disc electrode[5], a horizontally cast disc with a central head[5], and the plate electrode. Experiments were made with the Al-Si-Cu casting alloy LM-4 and with duralumin. Graphs were obtained by plotting contents of a number of elements against depths from the original cast surface. With LM-4 alloy the segregation was slight and sometimes not detectable, but with duralumin a pronounced segregation pattern was found in the casting from each of the moulds examined. The contents at each depth of machining were determined at three or more positions over the surface and averaged, and it was found that the scatter of contents at each depth was greater than the maximum difference in composition over the whole depth (3·5 mm.) shown by the graph. With the plate electrode, this scatter can be reduced to quite small dimensions by sparking at two standardised positions on each surface. This is illustrated in Fig. 4 ; (*a*) shows the curve and scatter for

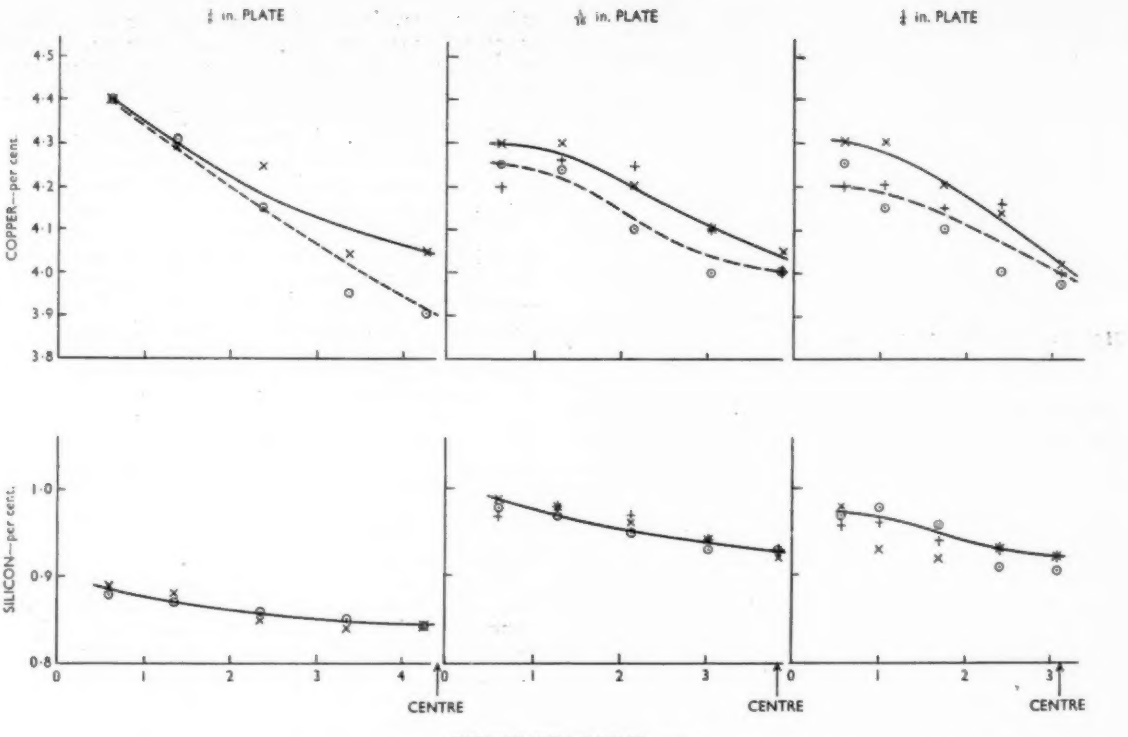

Fig. 3.—Variation in copper and silicon content with distance from the surface for $\frac{3}{8}$ in., $\frac{5}{16}$ in., and $\frac{1}{4}$ in. plate castings.

silicon when four positions are sparked, and (*b*) the same curve, but with greatly reduced scatter, when the two standard positions only are used. With the other castings the scatter could not be similarly reduced since the position of sparking cannot be varied in the same way.

So far, results show that segregation does occur in all the point-to-plane types of electrode castings examined, but the differences between the various castings have not yet been established clearly enough to enable a recommendation of practical superiority to be made. Although the effect of heterogeneity may be minimised by sparking only at certain areas and within limited depths, the ideal solution to the problem, i.e., the development of a completely segregation-free electrode casting which could be used for a large number of sparkings, does not yet appear to be in sight.

Segregation in Pencil Samples

Examination of the pencil type electrode consisted firstly of an attempt chemically and spectrographically to measure the variation in composition both along and across the casting, and later to determine the area of the sparking surface contributing to the spark.

It is obvious that the standard alloy electrodes used for calibration will be repeatedly sparked and resurfaced, and that the length of the pencil will diminish throughout its life. Consequently, it is important that the composition should not vary over the length of the pencil. This was investigated by three laboratories who sparked chill cast duralumin pencil electrodes of 6 mm. diameter against flat tipped graphite electrodes, removing 3 or 4 mm. from the metal electrode after each sparking until some 60–80 mm. had been consumed. Unfortunately, the results of these tests for the four or five

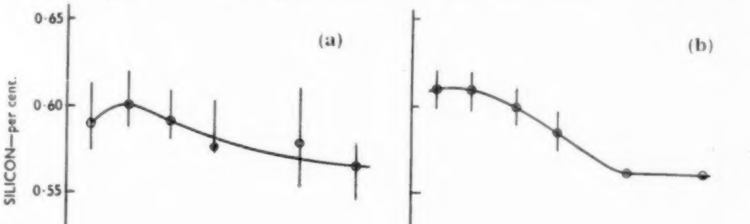

Fig. 4.—Variation and scatter for silicon when (a) four positions are sparked, and (b) two standard positions only are sparked. Note reduced scatter, as indicated by length of vertical lines, in (b).

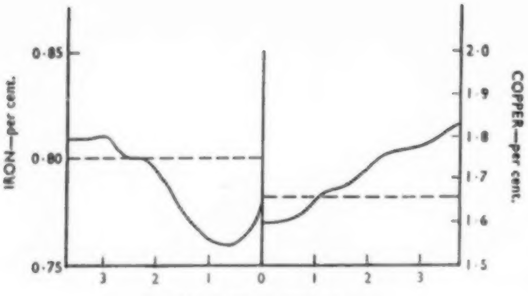

Fig. 5.—Variation in iron and copper content across a 8 mm. chill cast pencil in LM-2 alloy.

elements determined are contradictory, different members finding a tendency for different elements to increase in content with distance from the feeder head. Furthermore, in the curves plotted from the results, there appeared a tendency for the peaks for each element to occur at the same sparking. Subsequently, values for consecutive sparkings from wrought pencil electrodes of the same composition were plotted in a similar manner. These curves show a similar tendency for the peaks and inflexions to be reproduced in the same positions for two or three elements, but there is no evidence whatsoever of a tendency for the content of any element to increase or decrease over the course of 20 sparkings.

As the presence of longitudinal segregation in pencil electrodes would have an undesirable effect on the accuracy of standards, it is essential that the uniformity of composition over the length of the pencil should be established without doubt. Chemical analysis, or direct reading spectrography, might achieve a greater measure of success than the method described.

It was thought that transverse segregation might be investigated by exploring the cross section of pencil electrodes spectrographically using a mask to limit the spark to very small areas, but it was estimated that the exposure times would be far too long and that a special technique would be required. Subsequently it was found simpler to analyse chemically turnings from annular layers cut from the electrode, although this method suffered from the disadvantage that it was necessary to obtain the sample from a 1 in. length of the pencil in order to provide sufficient material for the chemical analysis. The values obtained in this way are, therefore, average compositions, and if there were marked longitudinal segregation in the pencil, would not necessarily represent the compositions at every point in the 1 in. length of electrode. A typical graph showing the iron and copper distribution across the section of a 8mm. chill cast pencil in the Al-Si-Cu alloy LM-2 is shown in Fig. 5.

Chemical analyses of this kind were made on a number of alloys cast in pencils of 6, 8 and 10 mm. diameter and curves showing the variation in copper, silicon and iron content were drawn. A typical series of curves for silicon in the alloy H10 are shown in Fig. 6.

From these curves it is apparent that segregation does occur across the transverse section of chill cast pencils, in a manner and intensity similar to that described earlier for the plate casting, the severity of the segregation varying with the alloy. The elements determined tend to be present in higher concentration at the outside of the casting than at the central core. Furthermore, Fig. 6 shows that the difference between centre and edge does not decrease when the diameter of the electrode casting is reduced from 10 to 6 mm.

When a pencil casting is machined to the final electrode diameter, part of the richer surface at the edge is removed and the remaining composition difference between centre and edge is consequently reduced. Nevertheless, when a pencil electrode is sparked, the whole of the surface of the tip in which this reduced range of composition exists is accessible to the spark, unlike the plate electrode in which only a small part of the cross section can be included in one sparking. This, depending upon the area affected by the spark, must result in the extremes in composition being averaged to some extent. Table I, which shows the iron and copper contents found chemically at varying distances from the central axis of a pencil electrode of duralumin illustrates, by a calculated mean content for central areas of increasing diameters, the extent to which the extreme differences are reduced.

It was realised that the actual area of the electrode tip which was subjected to the spark was of great practical importance, since this would determine whether the segregation discovered would significantly affect the accuracy of the spectrochemical analysis using pencil electrodes.

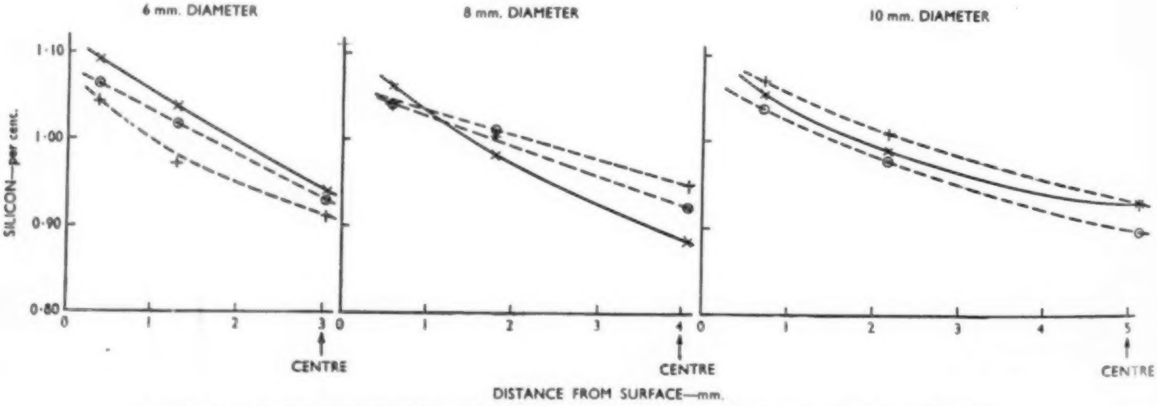

Fig. 6.—Effect of diameter of electrode on difference between centre and edge.

Area Affected by Spark

Some attempts were made, unsuccessfully, to measure the area contributing to the spark, using, firstly, pencils of the usual cast size machined to electrodes of decreasing diameters, and later pencils of different cast diameters machined to a standard 4·5 mm. It was thought that the method was not sufficiently sensitive for the small order of composition differences expected, and a technique was tried in which a large variation in composition was produced with composite electrodes.

In the initial experiments, a piece of N3 aluminium alloy wire (1·25% manganese) of 2 mm. diameter was introduced into an H10 aluminium alloy rod (manganese free), thus providing an area of comparatively high manganese content within an area of manganese-free alloy. Two series of electrodes were prepared, in one the insert was fitted concentrically, i.e., along the central axis, and in the other eccentrically 2 mm. from the axis. These composite electrodes, 6 mm. in diameter, were sparked against graphite counter electrodes of the same diameter, each electrode having a flat tip, and the apparent manganese content evaluated using a series of specially prepared low-manganese standards.

It was found that the apparent manganese content of the concentric composite electrode was approximately 50% higher than that of the electrode having an eccentrically placed insert. From these tests it became clear that the whole of the electrode tip does not contribute equally to the spectrum and that the centre makes a disproportionately large contribution.

At the same time, experiments were also carried out with an insert in a flat plate in order to obtain a value for the effective area with this type of electrode. The eccentricity, in this case, was achieved by simply displacing the electrode sideways so that the insert was offset a predetermined distance in relation to the axis of the pointed graphite counter electrode. Calculations from the manganese contents obtained indicated that, for the particular conditions obtaining, the area which would give an average content in agreement with the measured value would be a circle of 4·5 mm. diameter, although the area apparently affected by the spark was much greater—about 10 mm. (see Fig. 7). Confirmation was afforded by further tests in which (*a*) the insert was located half inside and half outside this circle, and (*b*) just outside the circle. The result from the former agreed with the calculated area, and with the latter position the

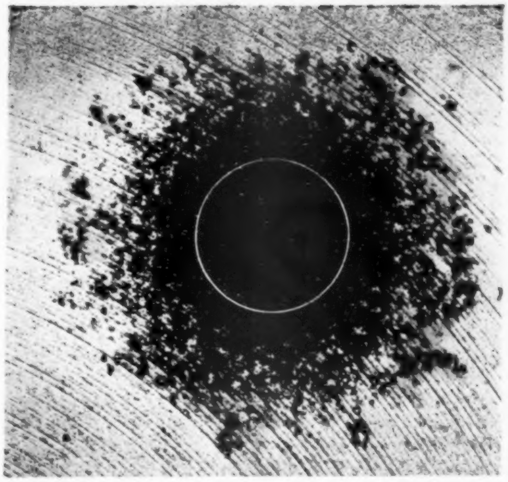

Fig. 7.—Photograph showing area of plate electrode affected by spark. × 5

value was within 0·01% of the manganese content of the basic H10 material.

A second series of tests was made with the flat electrode, using inserts of varying sizes, and a pointed graphite counter electrode, and the results are set out in Table II.

These results confirm the diameter of 4·5 mm. as the maximum width of the electrode surface contributing to the spectrum (last two lines of table) and also show the greater contribution of the centre of this area. It was, of course, realised that this calculated area would apply only to the particular electrical and other conditions which were used in the experiments and, further, that it was unlikely that it would be equally true for the pencil type electrode in which the area of the tip was limited to a circle of 6 mm. diameter.

A similar series of experiments was carried out with inserts of various diameters in pencil electrodes, but in these the materials were reversed, i.e., manganese-free H10 alloy inserts in manganese-containing N3 alloy electrodes. A further measure of effective areas was afforded by determining magnesium as well as manganese, since these two elements would vary in opposite directions with varying insert diameters. The 6–6·5 mm. diameter composite electrodes were sparked against flat-tipped graphite counter electrodes of the same diameter, and the results obtained appear in Tables III and IV.

Although each laboratory reported rather wide scatter for the individual values averaged in the above tables, the results from the three sources are in general agreement. They show, with very few exceptions, that the manganese content found is lower than the average content of the surface exposed to the spark, and that the magnesium content is higher than the theoretical average. The results, therefore, confirm the earlier findings that the centre of the electrode makes a disproportionately greater contribution to the spectrum than does the remainder of the surface. It is evident that even with the largest insert used, i.e., 5 mm., part of the discharge takes place at the outer edge of the electrode beyond the insert, since for both manganese and magnesium the contents found are approximately the theoretical averages for the whole surface and not simply the content of the insert.

TABLE I.

Distance from Centre—in.	Iron Content %		Copper Content %	
	Periphery	Central Area	Periphery	Central Area
0	0·464	—	3·64	—
0·025	0·474	0·470	3·73	3·70
0·050	0·485	0·478	3·81	3·76
0·075	0·496	0·485	3·87	3·81
0·100	0·509	0·493	3·91	3·85
0·125	0·522	0·501	3·95	3·87
0·150	0·536	0·510	3·98	3·90

TABLE II

Insert Diameter mm.	Mn Found %	Theoretical Mn % (based on active area 4·5 mm. diameter)
1	0·26	0·08
2	0·42	0·23
3·5	0·77	0·65
4	0·92	0·84
4·5	1·06	1·06 } by definition
5	1·06	1·06 } by definition

TABLE III

Diameter of Insert mm.	Manganese %				
	Lab. *A*	Lab. *B*	Theoretical Average*	Lab. *C*	Theoretical Average
2	—	—	—	1·09	1·09
3·5	0·74	0·75	0·80	0·74	0·86
4	0·61	0·66	0·67	0·66	0·76
4·5	0·52	0·45	0·55	0·59	0·64
5	0·40	0·38	0·40	0·47	0·51

* Manganese content of N3 pencils 1·25%, H10 inserts 0·03%.

TABLE IV

Diameter of Insert mm.	Magnesium %				
	Lab. *A*	Lab. *B*	Theoretical Average*	Lab. *C*	Theoretical Average
2·0	—	—	—	0·12	0·07
3·5	0·28	0·35	0·26	0·31	0·22
4·0	0·35	0·40	0·33	0·34	0·29
4·5	0·42	0·47	0·42	0·41	0·36
5·0	0·47	0·52	0·52	0·50	0·45

* Magnesium content of inserts 0·75%.

The scatter between the results obtained is of the order to be expected in experiments of this kind. Observation of the spark reveals that the discharge may be directed at a small area of the electrode surface for two or three seconds at a time or may tend to continue about the point, fortuitously selected, from which it originated. In a surface of non-uniform composition, therefore, it is unlikely that results will be reproduced exactly.

It has been emphasised earlier that the detailed results from these experiments apply only to the particular conditions imposed during the tests. This is rendered even more evident by some results which illustrate the effect of varying the inductance when sparking electrodes with gross segregation. With low inductance, the spark covers the whole surface of the electrode tip and even impinges on the sides of the pencil ; the smaller, quieter spark, associated with higher inductance, is much more restricted in the area it affects. The quantitative effect of varying inductance was demonstrated with the composite electrodes containing concentrically and eccentrically positioned inserts. With inductances up to 0·06 mH., the two electrodes gave identical manganese results, but with the more restricted spark with 0·13 mH., the electrode with the axial insert showed a much higher manganese content than the electrode with the eccentrically placed insert.

Similarly, the size and shape of the graphite counter electrode would have an important influence in the analysis of electrodes of non-uniform composition. It was observed, for example, although no quantitative determinations were made, that when a pointed graphite rod was used the spark was largely confined to the centre of the surface of the flat tip of the metal electrode, and so would tend to exaggerate any difference in composition between the centre and outer edge.

Comparison of Cast and Extruded Electrodes

At this stage in the investigation, having shown that segregation could occur in pencil electrodes, and that the electrode tip is not uniformly sampled by the spark, an attempt was made to measure the error introduced from this source. A number of pencil electrodes were machined from a duralumin extruded bar of 2 in. diameter—the bar was shown spectrographically to be free from segregation. The electrodes were all cut from positions equidistant from the central axis of the bar. Part of the bar was then melted under carefully controlled conditions, and a number of cast pencil electrodes and plates were produced.

Ten pairs of these cast pencil electrodes were sparked by each of the three laboratories under routine conditions, and the results compared with ten sparkings from a pair of the wrought pencils of identical composition. A similar comparison was made with the plate electrodes using a slice cut from the extruded bar as the wrought electrode. The average coefficients of variation for five elements are given in Table V. and show that, setting apart the results for copper which are based on only one series of values, the reproducibility using wrought electrodes is about 25% better than for cast electrodes. Whilst this is a significant difference, it is clear that with properly standardised methods, segregation in cast electrodes is not the most important factor determining the accuracy of the spectrographic method.

It is interesting to note that Mills and Hermon[6] found very little difference between the reproducibility of cast and extruded pencils of 6 mm. diameter for a number of alloys, and in fact reported a coefficient of variation for duralumin which was approximately 20% lower for cast pencils than for extruded rod.

Conclusions

It has been demonstrated that marked segregation may occur in aluminium alloys when cast in the plate type electrode, and that the greatest variations in composition are found through the thickness of the casting. This is not reduced by decreasing the thickness of the casting within the limits of practical castability. Non-uniformity of composition has also been found in other forms of flat cast electrodes, such as the A.S.T.M. vertical and horizontal disc castings.

In spite of this deficiency, the flat type of electrode is satisfactory for practical purposes, provided (*a*) it is machined and sparked at a definite depth below the cast surface, and (*b*) it is sparked in areas at fixed distances from the outer edge of the sample.

Segregation has also been shown to exist across the section of chill cast pencils, and as in the plate casting, cannot be prevented by a reduction in the thickness of the casting. The severity of the segregation is largely dependent on the alloy, and only a slight departure from uniformity was found with some alloys. Evidence of segregation along the length of pencil castings is at present inconclusive and a further investigation is recommended.

The pencil electrode appears to be satisfactory for normal routine analysis when sparked at a fixed distance from the end joining the feeder. More information is needed on its suitability when the pencil is repeatedly re-machined and sparked over the greater part of its length, and when high alloying contents are to be determined.

Comparison with wrought electrodes shows that the reproducibility of analysis results under routine conditions is slightly better with wrought electrodes than with cast. This difference is thought to indicate that segre-

TABLE V.—COEFFICIENTS OF VARIATION

	Cu*	Mg	Si	Fe	Mn
Cast Electrodes	4	4·3	5·3	4·7	3·8
Wrought Electrodes ..	1·2	3·4	4·2	3·2	3·3
Wrought/Cast %	30	79	79	68	87

* Based on only one series of results.

gation is not the most important contributory factor in the error of routine spectrographic analysis when the above precautions are taken. There is, however, justification for the opinion generally held that it becomes more important with the greater accuracy obtainable from direct reading instruments.

The investigators have measured, by means of composite electrodes, the area covered by the spark in point-to-plane and pencil electrodes, and have demonstrated that contribution is not uniform. In point-to-plane electrodes, the centre of the sparked area contributes more than the periphery. In flat tipped pencil electrodes, the centre again predominates, but there is also an abnormally high contribution from the edge of the electrode tip.

Acknowledgments

In addition to the authors, the following members of the ALAR Spectrochemical Sub-Committee took part in the joint investigation described in this paper: Dr. E. Schuer (Chairman), Mr. K. Dobson, Mr. R. C. Hipwell, Mrs. E. Thornton and Mr. B. E. Turner. The authors also acknowledge the assistance of the ALAR Chemists Committee, whose members carried out the many chemical analyses.

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Baird & Tatlock Northern Office

BAIRD & TATLOCK (LONDON), LTD., have opened new offices and showrooms at 58, Lever Street, Manchester (telephone Central 0937/8), where apparatus, instruments and chemicals from Baird & Tatlock (London), Ltd., and its subsidiary companies, Hopkin & Williams, Ltd., and W. B. Nicolson, Ltd., will be on view. This will give scientists in the North a better opportunity of inspecting new or improved instruments and apparatus, and obtaining advice on their operation and application.

A complete range of major instruments and representative stocks of apparatus, laboratory furnishings and spare parts, together with Hopkin & Williams fine chemicals, will be immediately available from the Manchester showrooms. In cases where items cannot

be supplied immediately, a frequent delivery service between London and Manchester will enable deliveries to be effected with the minimum delay. The new offices will be able to deal directly with orders from laboratories in the North of England, and in general provide many of the facilities previously only available in London.

Initially there will be a twice weekly delivery service to the Manchester office from the main London warehouse and factories, and a daily delivery service in the Manchester area by vans from the Manchester office. The Manchester vans will also provide a weekly delivery service to the North Lancashire region. It is hoped that at a later date a larger number of vans will be based on Manchester so that much more frequent deliveries will be made to all the major towns in the North of England, while delivery services between London and Manchester will be increased as the situation demands.

Aero Survey by Photography

BY means of photographic aerial survey, scientists can to-day interpret the nature of the earth far more comprehensively and quickly than was formerly possible when all surveying had to be done on foot. The new science of aero-surveying plays a vital role in the location and exploitation of natural resources in under-developed countries.

At the Kodak Gallery, 194, Regent Street, London, W.1, on January 10th, Mr. A. D. Dodds-Parker, M.P., Parliamentary Under-Secretary of State for Commonwealth Relations opened an exhibition showing the extensive part played by photography in aerial survey work. The exhibition will remain open to the public until January 29th, Mondays to Fridays 9.30 a.m. to 5 p.m., Saturdays 9.30 to 12.30 p.m. Admission is free.

Midlands Technical Quiz

AT a meeting at the Birmingham Exchange and Engineering Centre, sponsored by the Birmingham Metallurgical Society, on Thursday, December 2nd, 1954, the Dorothy Pile Trophy, which is competed for annually by teams taking part in the technical quiz on metallurgy, was won by the Birmingham School of Technology. Wednesbury County Technical College were second: five teams took part in the quiz. The Chairman was Mr. Howard Evans, President of the Birmingham Metallurgical Society and the Quiz Master was Mr. George Parkin, a Past President. Miss Dorothy Pile, who presented the trophy to the winning team, is also a Past President of the Society.

Honeywell-Brown Middlesbrough Office

HONEYWELL-BROWN LTD., have opened an area office at 119/121, Albert Road, Middlesbrough. Under the supervision of Mr. T. Halstead the activities of the Middlesbrough office will be co-ordinated with those of the branch office in Sheffield. The new office, which was opened by Mr. V. D. MacLachlan, Director and General Manager, is the seventh to be established in Great Britain. A Cardiff office was opened in October.

Extra Telephone Numbers

BRITISH Insulated Callender's Cables, Ltd., announce that their Branch Offices at Exeter and Plymouth each have an additional telephone number. Their numbers are now Exeter 67308 and 3514, and Plymouth 60257 and 65151.

Photographing Stretcher-Strain Markings with the Vickers Projection Microscope

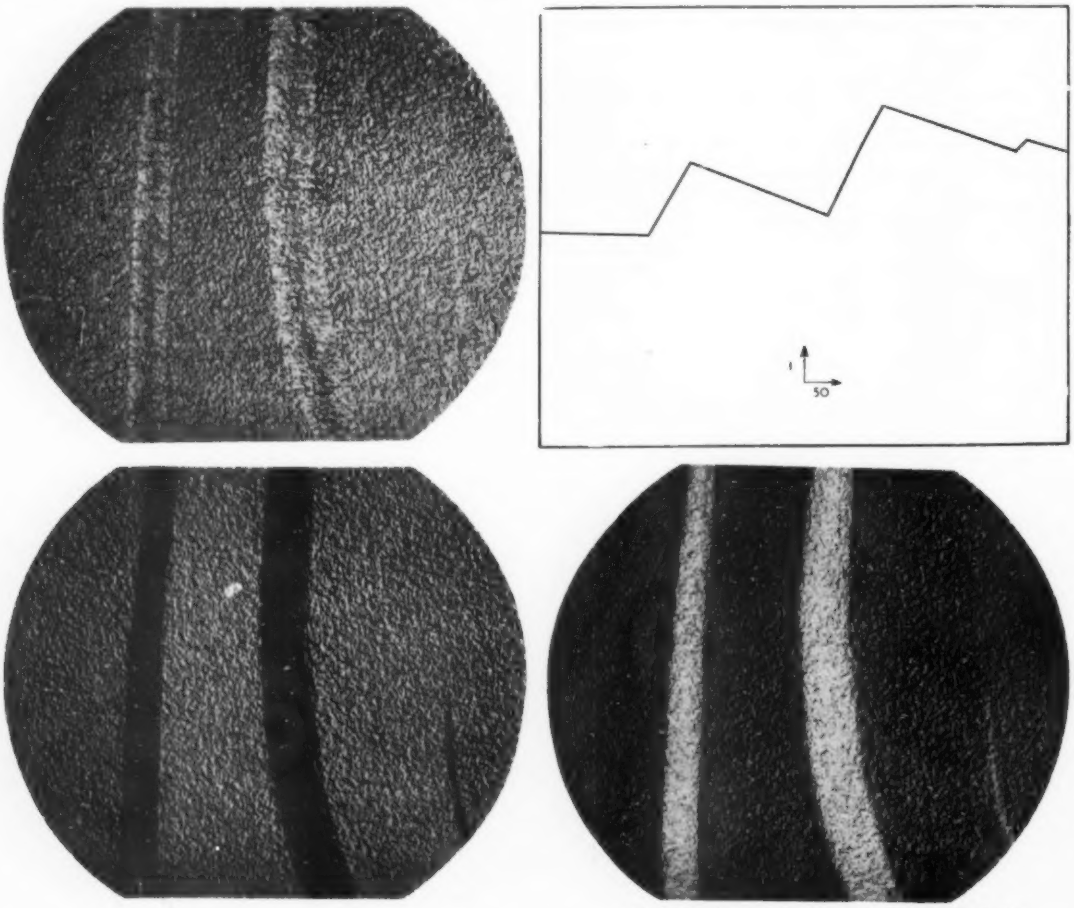
By T. D. Boxall and B. B. Hundy, B.Sc., Ph.D., A.I.M.
Mechanical Working Division, B.I.S.R.A., Sheffield.

One of the principal difficulties associated with photo-macrography is the provision of the correct illumination, and in the present article the authors describe a technique they have developed for the photography, at magnifications of $\times 3$ to $\times 15$, of stretcher strain markings on sheet, for which the angles of lighting and of viewing are very critical.

In the course of our work on the suppression of stretcher-strain markings in mild steel pressings, we have often found it necessary to photograph the markings on sheet tensile specimens and on other flat areas. The markings usually consist of small areas tilted at small angles to the main area of the sheet, and it is not possible to obtain good photographs of these areas by ordinary photo-macrographic methods; the angles of lighting and of viewing the specimen are very critical and vary from point to point along the specimen. We have used the method described by Loro* for photographing these markings at low magnifications (up to $\times 2$) but we have found it considerably easier to use the Vickers Projection Microscope for higher magnifications (viz., greater than $\times 3$).

* Loro, A., Metallurgia, 1953, **48**, 48.

(a) (b) (c) (d)



All photographs in this paper reduced ⅜ linear in reproduction

Fig. 1.—(a) Photo-macrograph using normal illumination; (b) surface profile across part of the specimen shown in (a), taken from Talysurf traces; (c) photo-macrograph using modified system with light source raised; (d) photo-macrograph using modified system with light source lowered. Photo-macrographs $\times 3$.

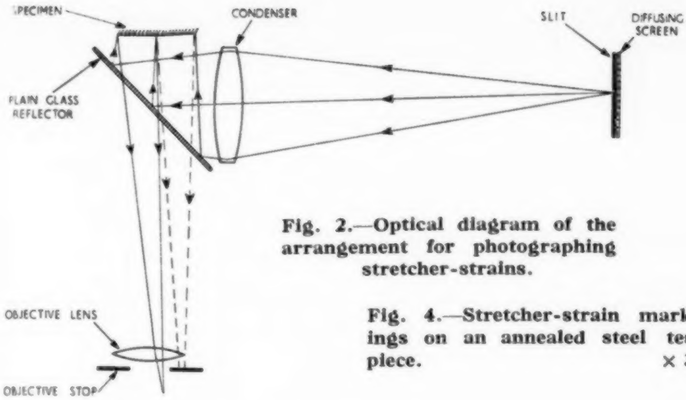


Fig. 2.—Optical diagram of the arrangement for photographing stretcher-strains.

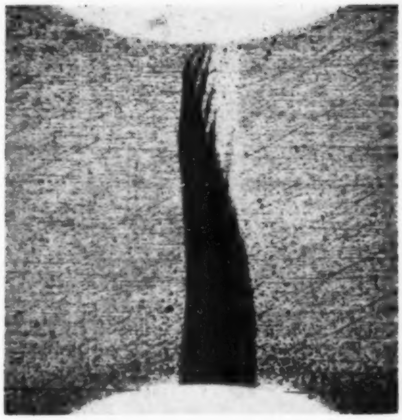


Fig. 4.—Stretcher-strain markings on an annealed steel test piece. × 3.

Details of the Method

The microscope is set up as usual for taking photomacrographs at low magnification using the vertical macro-illuminator. When this is used in the normal manner, the photograph obtained (Fig. 1*a*) shows little contrast. Fig. 1*b* shows the surface profile across part of this specimen and it can be seen that it consists of three stretcher-strain markings tilted with respect to the matrix by small angles of about 3°. Fig. 1*a*, does not show the markings distinctly, and certainly does not give an impression of plane areas tilted with respect to one another. By adjusting the illumination slightly, however, it was found possible to show up these markings very distinctly. The adjustment consisted of putting a $\frac{1}{8}$ in. horizontal slit near to the 2 in. square diffusing screen on the illumination bracket, stopping down the objective lens to *f*5·6 or *f*8, and raising or lowering the illumination bracket. As the light source is moved the illumination changes gradually, and the optimum position giving the maximum contrast between the stretcher-strain and the matrix can easily be found. Fig. 1*c* shows the same specimen when the light source was raised, and Fig. 1*d* shows its appearance when the light source was lowered.

The principle underlying this method is suggested in Fig. 2 showing light paths in the system. A flat surface appears evenly illuminated by this system, as all the

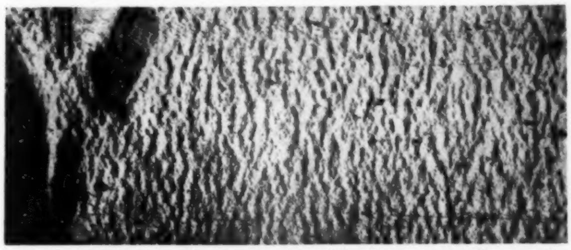


Fig. 5.—Striations inside the markings on a tensile specimen cut from steel sheet temper rolled 1·7% and aged for 3 months. ×3.

reflected light falls inside the aperture of the objective lens. Any pronounced change in the surface tilt, however, throws the light outside the lens aperture and that area appears darker. By a suitable choice of the position of the light source it is possible to obtain gradations in the darkening of the tilted areas depending on the respective angles of tilt ; this is illustrated in Fig. 3, which shows some stretcher-strain markings in an aluminium-magnesium alloy pressing.

The suggested method has also proved useful for distinguishing secondary markings inside the stretcher-strain. The stretcher-strains that form on working annealed mild steel specimens do not appear to have any

Fig. 3.—Stretcher-strain markings on an aluminium-magnesium alloy pressing. × 3.

Fig. 6.—Stretcher-strain marking on an annealed steel test piece. × 15.

sub-structure (Fig. 1 and Fig. 4), while the markings that appear on working aged temper-rolled specimens contain striations perpendicular to the rolling direction (Fig. 5).

The method outlined here enables photographs to be taken at magnifications varying from $\times$ 3 to $\times$ 7 with the $5\frac{1}{2}$ in. objective and from $\times$ 7 to $\times$ 15 with the $3\frac{1}{2}$ in. objective. Fig. 6 shows a portion of the stretcher-strain shown in Fig. 4 taken at a magnification of $\times$ 15. The results obtained with shorter focal length lenses at higher magnifications were not so satisfactory.

For maximum contrast the specimen has to be arranged so that the edge of the stretcher-strain is roughly vertical on the viewing screen. The sensitivity of the process is much less in the horizontal direction and any markings running in this direction are not so clearly distinguished. Most stretcher-strains occur in roughly parallel bands, so it is usually possible to rotate the specimen into a position of maximum sensitivity.

This method of photographing surface markings is not confined to stretcher-strain markings, but can be used for any study of surface topography involving changes in the tilt of the surface from point to point. Thus, it can be used to photograph local necks in strained specimens, or the markings that appear when mild steel is pulled in the blue brittle temperature range. The only apparent disadvantage of the method is that it cannot be used with the standard equipment for photographing large areas, and the magnification range is rather limited.

Employees' Long Service Recognised

In a good many firms it is now customary to recognise lengthy service on the part of employees with an award of some kind or other. That the occasion for such presentations should arise is a matter for congratulation, not only to the employees concerned, but to the firms themselves, for the fact that employees have stayed with them so long is an indication that working conditions have been satisfactory to them. A number of such presentations took place last month, brief particulars of which will be found in the following account.

Thomas Bolton & Sons, Ltd.

On December 6th last, over 60 employees of the Staffordshire works were entertained to lunch by the management, when gold watches or cheques were presented to the 10 who had completed a half-century of service with the firm. In addition, certificates were presented to 42 for 40 years' service and to 10 for 25 years' service. Among the recipients were Mr. S. Berrisford, Superintendent of the Oakamoor Works (50 years), and Mr. W. Cartwright, Research Manager (25 years). Members of the management present included Mr. W. F. Slater, Dr. W. E. Alkins, Mr. R. Badger, Mr. J. W. Newton, Mr. W. Cartwright, Mr. D. C. Bolton and Mr. V. B. Hysel.

Darwins, Ltd.

Mr. R. Willis and Mr. A. Torry, Directors; Mr. J. Robinson, Secretary; Mr. T. S. Chapman, Works Convenor; Mr. C. Boden, A.E.U. Convenor, and the Managers and Foremen of the departments concerned were among those present in the Senior Staff Canteen at Darwins, Ltd., Sheffield, on December 20th, when Mr. F. Thompson-Schwab (Chairman) made presentations to 18 employees of Darwins, Ltd., and Andrews Toledo, Ltd., who had served the firm for 25 years. Gold watches were presented to 17 male employees, while Miss D. Kibblewhite received a silver tea service.

Head, Wrightson & Co., Ltd.

A second presentation of long service awards took place at a dinner held at Head Wrightson's Teesdale Hall on December 3rd, when Mr. R. Miles, Chairman and Managing Director, supported by Sir John Wrightson, Bt., Vice-Chairman and Deputy Managing Director, and Mr. P. Wrightson, Deputy Managing Director, handed over handsome clocks to 14 employees with 50 years' service and 45 gold watches to those with 40 years' service. Mr. J. B. Bashford, a moulder with 50 years' service, replied to Mr. Miles' toast of "those who serve," and Mr. J. G. Allen, Director and General Manager of Head Wrightson Steel Foundries, Ltd., who had received a watch, proposed the toast "Head Wrightsons" to which Sir John responded.

McKechnie Brothers, Ltd.

The Widnes Branch of the McKechnie 25 Club held its sixth Annual Dinner at St. Helens on December 10th. Together with the Birmingham Branch the Club has a membership of 296, all of whom have completed 25 years' service with McKechnie Brothers, Ltd. Mr. J. D. McKechnie, Chairman and Managing Director of the Company, and President of the Club, presided, and in presenting awards for 25 years' service to seven new members, he expressed the hope that members of the Club would encourage newer employees to think and work on the right lines which they had found successful in the past.

Northern Aluminium Co., Ltd.

On December 13th and 17th, Mr. F. W. Bruce, Managing Director of Northern Aluminium Co., Ltd., presented watches to 16 Birmingham and 7 Banbury employees to commemorate their 25 years' service with the Company. The men were presented with aluminium watches weighing less than half-an-ounce each, specially made for the Company by one of the leading Swiss watchmakers: Miss Bunn and Miss Mazzucati received gold watches. Among the guests were Mr. H. C. Thomas, Mr. B. N. H. Thornley and Mr. C. P. Paton, Directors; Mr. L. Fletcher, Birmingham Works Manager; Mr. E. L. Ashley, Banbury Works Manager; the heads of the departments concerned; and employees who had already received similar awards, including four brothers with a total of 125 years' service.

Coke Oven Machines for India

The Wellman Smith Owen Engineering Corporation, Ltd., has received from Simon Carves, Ltd., a contract for the supply of two sets of coke oven machines to be installed at the Burnpur Steelworks of the Indian Iron & Steel Co., Ltd. The equipment will consist of two portal type coke pusher, coal leveller and door extractor machines; two coal charging cars (4 hopper type); three combined coke guide and door extractor machines; and eight clay carriers.

HALE AND HALE (TIPTON) LTD

(Producers of Fine Blackheart Malleable Iron)

Trading Difficulties Largely Surmounted

Mr. W. Edgar Hale on the achievements of British Industry

The 18th annual general meeting of Hale and Hale (Tipton), Limited, was held on December 15th at Dudley,

Mr. R. C. Leppington (Vice-Chairman & Managing Director) presided in the unavoidable absence of the Chairman, Mr. W. Edgar Hale, M.I. Mech. E.

The following is an extract from the Chairman's circulated statement :—

The Profit and Loss Account of the Holding Company shows a trading profit of £51,779, which compares with a figure of £89,208 for the previous year and shows a decrease of £37,429. There is a net profit for the year of £19,796. Last year the net profit amounted to £29,280 and there is thus a decrease of £9,484. The profits of the Subsidiary Companies have been retained in those Companies which is in accordance with the policy which your board has followed for many years. Your directors recommend a Final Dividend on the Ordinary Shares at the same rate of 17½%, less tax, to bring the total distribution for the year again to 25%, less tax.

The consolidated trading profit for the year is shown to be £76,886 as against £124,469 for the previous year and thus shows a decrease of £47,583. Taxation absorbs £35,958 and there is a consolidated net profit of £32,429 as compared with the consolidated net profit of £49,202 for the previous year, a decrease of £16,773.

TRADING CONDITIONS

It will be seen at once that the year's trading has not been as good as one could have desired, but on reflection, considering all the difficulties we have had to face by way of rising costs of raw materials, labour and transport, and reduced selling prices brought about by increased competition, we can be content that on the whole we have come through a difficult period quite well. Our very good name in the trade has stood us in good stead, and it would appear as though all is " set fair " for another period of steady trading, although, of course, the current year will in part be affected by the difficulties to which I shall refer later.

I stated last year that the bulk of our raw materials comes from the nationalised industries and we have no option but to accept any increases in prices that are made by those industries. Such increases have been made and these we have met, but unfortunately we were not able to counter these higher costs by increasing the selling prices of our product.

SALES AND PRODUCTION

We have had a difficult trading year as the slight recession we experienced during the latter part of 1953, continued through the early part of 1954. This position was reflected in the main by curtailment of programmes in the Agricultural and Motor Industries and was, in some measure, due to customers working off stocks, and reducing order cover.

The effect of this policy was to increase competition and cause a general reduction of prices, in some cases to almost uneconomical levels. It is evident that prices where necessary will require to be brought into line with present-day costs ; but, as in the past, this problem will be dealt with fairly and reasonably to ensure no more than a right and proper return for our endeavours.

Of recent months I am pleased to be able to report a substantial improvement in the order position, pressure now being on delivery rather than price, although the margin of net profit on much of the business has been reduced.

SUBSIDIARIES

Chatwins, Limited, produces the very well known domestic solid fuel appliances which are sold under the name of " Sunbeam " and have an excellent reputation in the market. There was a slight recession in demand during one part of the year over which we had no control, and resulted in a temporary reduction in output.

J. & J. Whitehouse (Tipton), Limited. Production, under the name of "Phoenix," of a great variety of domestic appliances in cast iron almost exclusively for export, is made by this subsidiary.

Hale Enamellers, Limited. This is a new subsidiary which your directors are developing to enable us to improve upon the enamelling requirements of Chatwins Limited in particular and also to fill what we feel to be a deficiency in the enamelling market generally.

CURRENT OUTLOOK

Provided we can keep politics out of industry, it would appear as though we can look forward nationally to a good period of prosperity, in which everyone will share ; and so long as the £ sterling remains at its present level, vis-a-vis the Dollar, our prosperity should continue for quite a time.

Those of us who can look back over the last half century cannot help but realise what immense strides forward British Industry as a whole has made. Not long ago, all that one heard was that British industry could not compete with the foreigner, and neither could it as long as the foreigner was able to maintain his own home market unmolested by tariff walls, while we were constantly being undersold at surplus prices, with the result that there was no solid foundation upon which our manufacturers could build. Since then, but alas much too late, British industry has shown the world what it can do, and I think we can be egotistical enough to suggest that to-day there is no country in the world to whom we take second place. Our scientific progress enjoys the admiration of the world, and from this progress has arisen our immense production of all kinds of commodities, mostly of the better grades, which the world is eager to have, provided our costs of production remain reasonable.

It is most interesting to read at times the official statistics relative to our exports, and to observe the immense rise which has been taking place year after year. Our only weakness is where the cheaper " bread and cheese " lines are concerned, in which we are unable to compete very successfully. However, I for one much prefer to see our native skill utilised in the production of higher grades of manufacture in which we excel.

The report was adopted.